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DARLINGTON NGS 'A' STANDBY GENERATOR #4
VIBRATION ACCEPTANCE TESTS

Report No 89-6-K

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ABSTRACT

Commissioning tests to determine acceptability of Standby Generator #4 (AC generator and power turbine) dynamic and vibration characteristics are described. Vibration levels and structural dynamic characteristics of the AC generator are considered acceptable. Velocity levels measured on the power turbine outboard bearing pedestal exceed the acceptance limit. The overall shaft displacement levels measured on the power turbine are acceptable at higher loads. Impact tests on the power turbine structure/skid show a structural natural frequency close to the operating speed. A first rotor critical speed of the AC generator - power turbine unit between 1440 rpm and 1536 rpm, as well as another possible rotor critical close to 3200 rpm was identified. A theoretical rotor critical speed analysis of the unit is recommended to determine the rotor dynamic characteristics.

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EXECUTIVE SUMMARY

DARLINGTON NGS 'A' STANDBY GENERATOR #4 VIBRATION ACCEPTANCE TESTS

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Mechanical Research Department

As part of the Darlington NGS commissioning program, acceptance tests were carried out on Standby Generator #4 to determine the vibration and dynamic characteristics of the AC generator and power turbine.

The overall bearing casing velocity and shaft displacement levels measured on the AC generator (at various loads) are considered acceptable. The structural dynamic characteristics of the AC generator are also considered acceptable.

Overall velocity levels measured on the the power turbine outboard bearing pedestal exceed the acceptance limit by a maximum of 70 percent at low loads (25 percent at higher loads) and is partially due to broad band excitation of system natural frequencies between 15 Hz and 20 Hz. Overall shaft displacement levels exceed the acceptance limit by a maximum of 34 percent at the lower loads; at loads of 20 MW and 26 MW, the levels are acceptable. Impact tests on the power turbine structure/skid show a natural frequency close to the operating speed (60 Hz). It is recommended that velocity spectra be obtained on the power turbine periodically to assess the effect of the structural natural frequency.

A rotor first critical speed of the AC generator - power turbine unit between 1440 rpm and 1536 rpm, as well as another possible rotor critical close to 3200 rpm was identified. A theoretical rotor critical speed analysis of the AC generator - power turbine unit, to determine the rotor dynamic characteristics, is recommended. Relatively high shaft displacements were measured at the AC generator bearings while passing through the first critical. It is recommended that the manufacturer indicate whether the levels are acceptable. Amplification factors while going through the first critical are considered acceptable.

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To Mr. D.R. McQuade
Technical Manager
Darlington NGS 'A'

DARLINGTON NGS 'A' STANDBY GENERATOR #4 VIBRATION ACCEPTANCE TESTS

1.0 INTRODUCTION

Vibration acceptance tests were carried out on four Standby Generators SG #1 - SG #4, as part of the Darlington NGS 'A' commissioning program. Mechanical Research (Ontario Hydro) was requested to carry out the vibration commissioning program as specified by Pratt & Whitney and Darlington NGS 'A' Operations. This report discusses the results of the tests on Standby Generator #4. The results of the vibration acceptance tests on Standby Generators #1, #2 and #3 can be found in references 1, 2 and 3, respectively.

The principal objectives of the tests were to:

1) Evaluate the acceptability of the machine vibration and dynamic characteristics with respect to Pratt & Whitney's contractual obligations as well as Ontario Hydro's specifications and/or industry standards.

2) Obtain baseline vibration data for use in future machine monitoring.

3) Make recommendations for corrective action if vibration levels are in excess of the limits specified in the relevant tendering documents or specifications.

The general turbine-generator arrangement is shown in Figures 1, 2 and 3. The main components are the gas generator, the power turbine (Rolls Royce) and the AC generator (Brush) with a rated output of 27250 KVA at 3600 rpm.

This report presents the vibration data obtained on the power turbine and AC generator.

2.0 INSTRUMENTATION, TEST METHOD AND MEASUREMENTS

2.1 Instrumentation

The main components of the instrumentation used in obtaining the various measurements are listed in Table 1 and are further discussed in Sections 2.1.1 to 2.3, inclusive.

2.1.1 On-line Vibration Monitoring System

Each turbine-generator unit has an on-line vibration monitoring system which measures the overall vibration levels at selected locations on the gas generator, power turbine and AC generator. The permanently installed vibration transducers and their locations are outlined below :

1. AC Generator - The two journal bearings of the AC generator are equipped with two displacement transducers per bearing, mounted radially at 90 degrees to each other. These displacement transducers (Bently Nevada Model 21505-00-12-60-02) measure the generator shaft motion relative to the bearing housing.

2. Power Turbine - Two displacement transducers (Bently Nevada Model 21505-00-12-60-02) are mounted radially at 90 degrees to each other on each of the two journal bearings, and measure the power turbine shaft motion relative to the bearing housing.

A velocity transducer (Bell and Howell Type 4-103-0001) is also mounted vertically on an adapter plate bolted to the top of the bearing pedestal across the centre line of the power turbine inboard bearing and measures the power turbine inboard pedestal velocity.

3. Gas Generator - A velocity transducer (Bell and Howell Type 4-125-L209) is mounted vertically on the gas generator intermediate casing and measures the gas generator casing velocity.

The signals from the four displacement transducers (installed on the AC generator) and the two velocity transducers are monitored. The vibration amplitudes are displayed by the on-line vibration monitoring system. The shaft displacement amplitudes are measured in units of micrometers peak-peak; and the power turbine inboard bearing pedestal and gas generator intermediate casing velocities are measured in units of mm/s rms. The signals from the power turbine displacement transducers are not monitored by the on-line monitoring system.

2.1.2 Transducers used for Vibration Acceptance Tests

The permanently installed shaft displacement transducers at the AC generator and power turbine bearings in the X and Y directions (Figures 2, 4, 5 and 6) were utilized for the vibration acceptance tests. Their output signals were continuously monitored throughout the tests. The permanently installed velocity transducers were only periodically monitored.

Accelerometers were mounted on the power turbine inboard bearing casing and the AC generator bearing casings in the X, Y and axial directions (Figures 4 and 5). Accelerometers were also mounted on the power turbine outboard bearing pedestal (in line with the bearing) in the horizontal, vertical and axial directions (Figure 6). These accelerometers were used to measure the bearing casing velocities.

A photoelectric tachometer probe (Bruel & Kjaer MM 0024) was installed at the exciter end of the generator to provide a reference mark for phase angle and shaft speed measurements.

2.2 Test Method

The test procedure for the Standby Generator unit is outlined below :

1. The cold soaked (minimum 4 hours since last run) unit was started, synchronized and the load raised to full load for the ambient temperature, at the maximum allowable rate. The unit was held at full load for approximately one hour. All vibration signals were recorded on magnetic tape during runup and full load operating conditions.

Synchronous speed is 3600 rpm (60 Hz).

2. The load was reduced at the maximum rate and the unit was shutdown.

3. The unit was restarted within 20 minutes of fuel shutoff (hot start) and the load raised to full load for the ambient temperature at the maximum allowable rate. Vibration signals were recorded during runup.

In order to evaluate the unit's vibration characteristics under different loads, the unit's power was decreased from 100% (maximum load attainable) to 0% (synchronous idle) in increments of approximately 25%. Loads of 26 MW (maximum load attained), 20 MW, 13 MW, 7 MW and 0 MW were selected. At each load, the unit was allowed to stabilize before the vibration signals were recorded.

4. From synchronous (3600 rpm) idle, the speed was reduced to the minimum power turbine controlled speed (approximately 88% synchronous speed) then increased slowly to the trip speed (approximately 110% synchronous speed). The unit was allowed to trip and rundown to zero speed. All vibration signals were continuously recorded during this period of speed changes.

5. Structural dynamics testing was carried out with the unit not running.

2.3 Measurements

2.3.1 Overall Vibration Levels

The bearing casing overall velocity levels were determined from accelerometer (Bruel & Kjaer Model 4368, Endevco Model 7707-1000) signals which were integrated to velocity and then analyzed with a Bently Nevada Digital Vector Filter (DVF 3). True peak and RMS overall velocity levels were measured.

Shaft overall displacement levels were obtained by analyzing the displacement transducer signals with the DVF 3.

2.3.2 Velocity and Displacement Spectra

Velocity and displacement spectra were generated from the accelerometer signals (integrated once) and displacement signals, respectively, by performing a Fast Fourier Transform (FFT) on the digitized signal.

2.3.3 Bode Plots

The shaft displacement and casing velocity signals recorded during the periods of unit runup and rundown were analyzed using a computer managed data acquisition and analysis system developed

by Mechanical Research, Ontario Hydro. Bearing housing velocity and shaft displacement magnitude and phase, at filtered 1 x shaft rotating frequency, versus generator shaft speed were calculated and plotted (Bode plot).

The Bode plots which show the rotor or casing response in both amplitude and phase as a function of shaft rotor speed were used to identify the rotor and structural natural frequencies of the AC generator and power turbine.

Bode plots produced using shaft displacement transducer signals may be inaccurate if the signal from the transducer includes any appreciable amount of shaft bow or runout (ie, any deviation in the shaft surface which produces a transducer output which is not related to shaft vibration). For this reason, both uncompensated and compensated (ie, compensated for bow and runout by subtracting the slowroll vector from the displacement vector) Bode plots were produced. Compensation is further discussed in Appendix A.

2.3.4 RPM Spectral Maps

Displacement and velocity spectra were generated from the transducer signals at various periods during runup and reproduced as a three-dimensional RPM spectral map.

2.3.5 Impact Spectra

AC generator and power turbine structural natural frequencies were determined by impact testing. With the unit not running, the AC generator and power turbine structures were excited throughout a range of frequencies (5-500 Hz) with a hammer having an elastomeric tip and instrumented with a force transducer. The input force (hammer) and the motor response (accelerometer signal) signals were fed simultaneously into a dual channel FFT analyzer (Ono Sokki CF 920) which calculated the input and response spectra as well as the compliance transfer function. The validity of the transfer function was checked by the coherence of the input and response signals. The ambient noise was reduced by averaging the results of eight impacts.

All impact tests were performed when the unit was cold and not running.

3.0 RESULTS AND DISCUSSION

3.1 Overall Casing Velocity and Velocity Spectra

Overall casing velocity measured on the AC generator and power turbine at the various loads from 0 to 26 MW are summarized in Table 2 and Table 3, respectively. According to the Darlington NGS tendering document, the lateral vibration level measured on the bearing housings should not exceed 2.8 mm/s rms for acceptance purposes.

All overall velocity levels were obtained from the unfiltered (5 Hz - 1000 Hz) velocity signals.

3.1.1 AC Generator - Overall Casing Velocity and Velocity Spectra

The maximum overall velocity measured is 0.5 mm/s rms and was obtained on the outboard bearing casing (axial direction) and the inboard bearing casing (Y-direction) at loads of 20 MW and 26 MW (Table 2). The maximum overall peak velocity is 1.3 mm/s. Overall velocity vibration levels measured on the AC generator bearing casings are considered acceptable.

Velocity spectra obtained at the six measurement locations on the AC generator for the various loads are shown in Figures 7 - 36 (Table 6). These spectra show that the main frequency components are generally at 1 x and 2 x synchronous frequency. The vibration amplitudes at these frequencies are considered acceptable and are listed in Table 2.

3.1.2 Power Turbine - Overall Casing Velocity and Velocity Spectra

The maximum overall RMS and peak velocity measured on the inboard bearing housing is 2.0 mm/s and 4.7 mm/s, respectively (Table 3). These inboard bearing casing overall velocity levels are considered acceptable.

The overall velocity levels measured on the outboard bearing pedestal in the horizontal and axial directions (Table 3), at all load conditions, are considered acceptable. In the vertical direction, the acceptable limit of 2.8 mm/s rms is exceeded at all five load conditions. The maximum overall RMS and peak velocity measured in the vertical direction is 4.8 mm/s and 10 mm/s, respectively. Table 3 shows that the overall velocity level in the vertical direction is reduced at the higher loads and at 26 MW it ranges from 2.4 mm/s to 3.5 mm/s rms.

Velocity spectra obtained on the power turbine bearing casing/pedestal are shown in Figures 37 - 66 (Table 7). The spectra obtained on the outboard bearing pedestal in the horizontal and vertical directions (eg, Figures 40 and 41) show that in addition to the main frequency component at 60 Hz, there is a broader spectral band centred between 15.3 Hz and 19.5 Hz (depending on the measurement direction). This spectral band is due to a broad band frequency excitation (most likely due to flow through the turbine) of the power turbine system natural frequencies close to 15.3 and 19.5 Hz. This excitation of the system natural frequencies is partially responsible for the relatively high velocity levels measured on the outboard bearing pedestal in the vertical direction.

The vibration amplitudes at 1 x and 2 x synchronous frequency are listed in Table 3.

3.2 Overall Shaft Displacement and Displacement Spectra

Overall shaft relative displacement levels measured on the AC generator and power turbine at various loads from 0 to 26 MW are summarized in Table 4 and Table 5, respectively. According to the Darlington NGS tendering document, the maximum vibration of the shaft relative to the bearing casing should not exceed 60 micrometers peak to peak for acceptance purposes.

The sensitivity of the displacement transducers is 7.87 millivolts/micrometer. All overall shaft displacement levels were obtained from the unfiltered (5 Hz - 1000 Hz) signals.

3.2.1 AC Generator - Overall Shaft Displacement and Displacement Spectra

The maximum overall displacement level measured is 21 μm p-p (peak-peak) and was obtained at the inboard bearing in the X-direction (Table 4). Overall shaft displacement levels measured on the AC generator are considered acceptable.

Shaft displacement spectra obtained on the AC generator for the various loads are shown in Figures 67 - 86 (Table 6). These spectra show that the main frequency component is at 60 Hz. The displacement levels at 1 x and 2 x synchronous frequency are listed in Table 4.

3.2.2 Power Turbine - Overall Shaft Displacement and Displacement Spectra

Overall shaft displacement levels measured on the power turbine at the higher loads are considered acceptable. However, at lower loads, the overall levels in the Y-direction exceed the 60 μm p-p acceptance limit (Table 5). The maximum overall displacement level measured is 80 μm p-p and was obtained at the inboard bearing in the Y-direction at a load of 0 MW.

Shaft displacement spectra obtained on the power turbine at the various loads are shown in Figures 87 - 106 (Table 7). In addition to the main frequency component at 60 Hz, these spectra show a broad spectral response below 60 Hz. This response is most likely caused by a broad band excitation of the system natural frequencies. The fluctuation in the overall relative displacement levels (Table 5), as well as the high overall levels at the lower loads can be partially attributed to this random broadband excitation.

The displacement levels at 1 x and 2 x synchronous frequency are listed in Table 5.

3.3 Cold Start Runup

3.3.1 AC Generator - Cold Start Runup

Figures 107 - 116 (Table 6) show the 1 x RPM filtered bode plots (500 rpm to 3600 rpm) of the AC generator velocity and displacement levels obtained during the cold start runup. Compensated and uncompensated bode plots are shown for the shaft displacement signals. A slow roll vector at approximately 500 rpm is used for compensation.

The bode plots of the filtered shaft displacements and casing velocities (X and Y directions) show a first rotor critical speed at 1536 rpm (25.6 Hz). Bode plots of the inboard and outboard casing velocities in the X-direction (Figures 107 and 110) also show a peak in the response at 2138 rpm (35.6 Hz) due to the presence of a structural natural frequency close to 35 Hz. Impact spectra obtained on the generator outboard bearing casing in the axial and vertical directions (Figures 208 and 209) and on the inboard casing in the axial direction (Figure 212) show a structural natural frequency close to 35 Hz.

The filtered (1 x RPM) velocity levels measured on the inboard and outboard bearing casings during the runup (Figures 107 - 112) do not exceed 2.2 mm/s peak. The maximum filtered compensated shaft displacement occurs while passing through the first rotor critical speed at 1536 rpm (Figures 113 - 116). Maximum filtered compensated shaft displacements of approximately 92 μm p-p and 75 μm p-p were measured at the outboard bearing (Y-direction, Figure 114) and inboard bearing (Y-direction, Figure 116), respectively, while passing through the critical. Amplification factors while going through the first critical were calculated from the four shaft displacement bode plots. Appendix B describes how amplification factors are determined. The calculated amplification factors range between 3.8 and 4.2 (depending on the measurement location and direction) and are considered acceptable. The American Petroleum Institute Standard 616 recommends that amplification factors should not exceed 8 while going through criticals; factors less than 5 are preferred/4/.

3.3.2 Power Turbine - Cold Start Runup

Figures 117 - 126 (Table 7) show the 1 x RPM filtered bode plots (500 rpm to 3600 rpm) of the power turbine velocity and displacement levels obtained during the cold start runup.

Compensated and uncompensated bode plots are shown for the shaft displacement signals. A slow roll vector at approximately 500 rpm is used for compensation.

The filtered (1 x RPM) velocity levels measured on the inboard bearing casing (Figures 117 - 119) and outboard bearing pedestal (Figures 120 - 122) do not exceed 3.8 mm/s peak and 4.9 mm/s peak, respectively, during the runup. The filtered compensated shaft displacement levels (Figures 123 - 126) do not exceed 37 μm p-p during runup.

The bode plots of the filtered casing velocities show peaks in the response at 1050 rpm (17.5 Hz, Figures 117 - 119, and 122), 2200 rpm (36.6 Hz, Figures 119 and 122), 2380 rpm (39.7 Hz, Figures 119 and 122) and close to 3000 rpm (50 Hz, Figure 117). These peaks are due to amplification of the casing response by structural natural frequencies. Impact spectra obtained on the power turbine inboard and outboard bearing pedestals (Figures 214 - 219) show structural natural frequencies close to these frequencies of peak response.

3.4 Hot Start Runup

Bode plots (filtered 1 x RPM) and RPM spectral maps of the casing velocity and shaft displacement levels measured on the AC generator and power turbine during the hot start runup, are discussed in the following subsections.

Compensated and uncompensated bode plots are shown for the shaft displacement signals. The slow roll vector at approximately 500 rpm is used for compensation. The bode plots show the 1 x RPM filtered amplitude and phase from approximately 500 rpm to overspeed. This runup speed range was achieved by combining the hot start runup (0 rpm - 3600 rpm) with the runup from 3600 rpm to overspeed (Section 2.2). There was a time lapse of approximately 90 minutes between the two runups.

3.4.1 AC Generator - Hot Start Runup

Figures 127 - 136 (Table 6) show the 1 x RPM filtered bode plots of the AC generator velocity and displacement levels obtained during the hot start runup.

The filtered (1 x RPM) velocity levels measured on the inboard and outboard bearing casings in the three directions (Figures 127 - 132) do not exceed 2.2 mm/s peak during the runup. The maximum filtered compensated shaft displacement occurs while passing through the first rotor critical speed at 1440 rpm (Figures 133 - 136). Maximum filtered compensated shaft displacements of approximately 94 μm p-p and 92 μm p-p were measured at the outboard bearing (Y-direction, Figure 134) and inboard bearing (Y-direction, Figure 136), respectively, while passing through the critical. Amplification factors for the first critical (hot runup), calculated from the four shaft displacement bode plots, range between 4.9 and 5.3 and are considered acceptable.

The difference between the hot start rotor first critical speed (1440 rpm) and the cold start first critical (1536 rpm) can most likely be attributed to temperature effects (different rotor and bearing oil temperatures) which may alter the rotor dynamic characteristics.

The peak in the response close to 2000 rpm is due to the presence of a structural natural frequency as discussed in Section 3.3.1.

RPM spectral maps of the bearing casing velocities and shaft displacements (uncompensated) obtained during the hot start runup are shown in Figures 147 - 156 (Table 6).

3.4.2 Power Turbine - Hot Start Runup

Figures 137 - 146 (Table 7) show the 1 x RPM filtered bode plots of the power turbine velocity and displacement levels during the hot start runup.

The maximum filtered (1 x RPM) velocity level measured on the inboard bearing casing during runup (Figures 137 - 139) is 9 mm/s peak and occurred in the axial direction while passing through a structural natural frequency close to 40 Hz (Figure 139). On the outboard bearing pedestal, a maximum filtered velocity of approximately 8 mm/s peak was measured (axial direction, Figure 142). The filtered compensated shaft displacement levels measured at the inboard and outboard bearings (Figures 143 - 146) do not exceed 58 μm p-p during the runup.

Several of the peaks seen in the bode plots of the bearing casing/pedestal velocities (Figures 137 - 142) were noted earlier in Section 3.3.2. In addition, the bode plots of the inboard bearing casing velocity in the X and Y directions (Figures 137 and 138) show a peak close to the synchronous speed (3600 rpm). This peak in the response can be attributed to the presence of a structural natural frequency close to 60 Hz. Impact spectra obtained on the power turbine pedestal and skid in the vertical direction (Figures 215 and 221) show a structural natural frequency at 61 Hz.

RPM spectral maps of the bearing casing/pedestal velocities and shaft displacements (uncompensated) obtained during the hot start runup are shown in Figures 157 - 166 (Table 7).

3.5 **Rundown From Overspeed**

Bode plots (filtered 1 x RPM) and RPM spectral maps of the casing velocity and shaft displacement levels measured on the AC generator and power turbine during the rundown from overspeed, are discussed in the following subsections. The rundown from overspeed follows the hot start and incremental load changes (Section 2.2 Item 4).

Compensated and uncompensated bode plots are shown for the shaft displacement signals. The slow roll vector at approximately 500 rpm is used for compensation.

3.5.1 AC Generator - Rundown From Overspeed

Figures 167 - 176 (Table 6) show the 1 x RPM filtered bode plots of the AC generator casing velocities and shaft displacements obtained during the rundown.

The filtered (1 x RPM) velocity levels measured on the inboard and outboard bearing casings in the three directions (Figures 167 -172) do not exceed 2.4 mm/s peak during the rundown. The maximum filtered compensated shaft displacement occurs while passing through the first rotor critical speed at 1442 rpm (Figures 173 - 176). Maximum filtered shaft displacements (compensated) of approximately 73 μm p-p and 75 μm p-p were measured at the outboard bearing (Y-direction, Figure 174) and inboard bearing (Y-direction, Figure 176), respectively, while passing through the critical. Amplification factors for the first critical, calculated from the four shaft responses on rundown, range from 4.8 to 5.8 and are considered acceptable.

RPM spectral maps of the bearing casing velocities and shaft displacements (uncompensated) obtained during the rundown are shown in Figures 187 - 196 (Table 6).

3.5.2 Power Turbine - Rundown From Overspeed

Figures 177 - 186 (Table 7) show the 1 x RPM filtered bode plots of the power turbine velocity and displacement levels obtained during the rundown.

The maximum 1 x RPM velocity component obtained on the inboard bearing casing during rundown (Figure 177 - 179) is 6.4 mm/s peak and occurred in the axial direction while passing through a structural natural frequency close to 40 Hz (Figure 179). On the outboard bearing pedestal, a maximum filtered velocity of approximately 11 mm/s peak was measured in the vertical direction while passing through a structural natural frequency close to 17 Hz (Figure 181). The filtered compensated shaft displacement levels measured at the inboard and outboard bearings during rundown (Figures 183 - 186) do not exceed 35 μm p-p.

RPM spectral maps of the bearing casing velocities and shaft displacements (uncompensated) obtained during the rundown are shown in Figures 197 - 206 (Table 7).

3.6 Structural Natural Frequencies

3.6.1 AC Generator - Structural Natural Frequencies

Compliance transfer function spectra obtained on the AC generator outboard and inboard bearing casings in the horizontal, vertical and axial directions are shown in Figures 207 - 212. These impact spectra show no structural natural frequencies close to the synchronous speed (60 Hz) or to twice the synchronous speed (120 Hz).

An impact spectrum obtained on the generator frame in the horizontal direction (Figure 213) shows a structural natural frequency at 65.5 Hz. This natural frequency is sufficiently removed from the synchronous speed and is not likely to cause any significant vibration amplification.

3.6.2 Power Turbine - Structural Natural Frequencies

Compliance transfer function spectra obtained on the power turbine structure and skid from impact testing are shown in Figures 214 - 221. Impact spectra obtained on the power turbine inboard bearing pedestal (vertical direction, Figure 215) and on the inboard end of the power turbine skid (vertical direction, Figure 221) show a structural natural frequency (at 61 Hz) close to the synchronous speed.

Structural natural frequencies appear to be sufficiently removed from 2 x synchronous speed.

Structural natural frequencies at or close to the synchronous speed are generally considered unacceptable since they can amplify the casing response significantly, unless the mode is sufficiently damped.

The 60 Hz component of the power turbine velocities measured on the inboard bearing casing and outboard bearing pedestal (Table 3) are presently considered acceptable or marginally acceptable, depending on the measurement location and load. However, the vibration amplitude at 60 Hz is dependent on the level of excitation at this frequency. Should this excitation increase

in the future (most likely due to increased unbalance), amplification of the casing response by the structural natural frequency may result in unacceptable levels of vibration.

3.7 Rotor Natural Frequencies / Critical Speeds

The first rotor critical speed of the AC generator - power turbine unit, identified during runup and rundown (Sections 3.3 to 3.5.2) lies between 1440 rpm (24 Hz) and 1536 rpm (25.6 Hz). No other rotor critical speeds within the speed range from zero to overspeed were positively identified from the runup and rundown tests. However, bode plots of the power turbine inboard shaft displacement obtained during the runup and rundown show a peak in the rotor response close to 3200 rpm (Figures 123, 124, 143 and 183), and may indicate a second rotor critical speed.

4.0 CONCLUSIONS

4.1 The overall shaft displacement and bearing casing velocity levels measured on the AC generator, at the five load conditions ranging from 0 MW to 26 MW, are considered acceptable.

4.2 The overall velocity levels measured on the power turbine inboard bearing casing, and on the outboard bearing pedestal in the horizontal and axial directions, at five loads ranging from 0 MW to 26 MW, are considered acceptable.

The overall velocity levels measured on the outboard bearing pedestal in the vertical direction exceed the acceptance limit of 2.8 mm/s rms at all five load conditions tested. The maximum overall velocity was measured at 0 MW and ranges from approximately 1.25 to 1.7 times the acceptance level. At the higher loads the overall velocity level is reduced, and at 26 MW it ranges from 0.86 to 1.25 times the acceptance level. These relatively high velocity levels can be partially attributed to a broad band excitation of system natural frequencies between 15 Hz and 20 Hz.

The overall shaft displacement levels measured at the inboard and outboard bearings of the power turbine exceed the acceptance limit (60 μm p-p) by a maximum of 34 percent at the lower loads. At loads of 20 MW and 26 MW, the overall displacement levels are acceptable.

4.3 The maximum filtered (1 x RPM) compensated shaft displacement levels measured at the inboard and outboard bearings of the power turbine during hot and cold start runup and hot rundown do not exceed 58 μm p-p.

4.4 The maximum filtered shaft displacement measured on the AC generator occurred while passing through the first rotor critical (1440 rpm - 1536 rpm). Maximum filtered compensated shaft displacements of approximately 94 μm p-p and 92 μm p-p were measured at the outboard and inboard bearings, respectively, while passing through the critical and occurred during the hot start runup. A maximum displacement level of approximately 92 μm p-p was also measured during the cold start runup while passing through the first critical. These levels are considered relatively high.

Amplification factors (AC generator) while passing through the first critical during cold and hot start runup, and hot rundown range from 3.8 to 5.8. These amplification factors are considered acceptable.

4.5 Structural dynamics testing of the AC generator indicates that all structural natural frequencies are sufficiently removed from the synchronous speed (60 Hz) and twice the synchronous speed.

4.6 Structural dynamics testing of the power turbine shows a structural natural frequency of the power turbine pedestal/skid close to the synchronous speed. The velocity amplitudes at 1 x synchronous frequency are, at present, acceptable or marginally acceptable depending on the measurement location and load. However, increased levels of excitation at the synchronous frequency (most likely due to unbalance) combined with the possible amplification of the casing response by the structural natural frequency could result in unacceptable levels of vibration.

No structural natural frequencies of the power turbine appear to be close to 2 x synchronous speed.

4.7 The first rotor critical speed of the AC generator - power turbine unit, identified during runup and rundown, is between 1440 rpm (24 Hz) and 1536 rpm (25.6 Hz). Another possible rotor critical speed close to 3200 rpm was identified. No other rotor critical speeds within the speed range from zero to overspeed were positively identified from the runup and rundown tests.

5.0 RECOMMENDATIONS

5.1 It is recommended that velocity spectra be obtained on the power turbine inboard and outboard bearing pedestals periodically to obtain a trend of the 60 Hz component. If this component increases significantly, remedial action should be taken. Detuning the structural natural frequency near the synchronous speed would be one possible solution.

5.2 It is recommended that a theoretical rotor critical speed analysis of the AC generator - power turbine unit be carried out to determine the rotor dynamic characteristics.

5.3 Since the standby generators are routinely started up and may experience numerous starts during the life of the plant, it is recommended that the manufacturer indicate whether the relatively high shaft displacement levels measured on the AC generator, during the hot and cold start runups, are acceptable.

Approved:

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Mechanical Research Dept

Submitted by:

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P. Hoogendam
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REFERENCES

1. N. Jagan, P. Hoogendam, "Darlington NGS 'A' Standby Generator #1 - Vibration Acceptance Tests", Ontario Hydro Research Division Report No 88-241-K, 1988.

2. N. Jagan, P. Hoogendam, "Darlington NGS 'A' Standby Generator #2 - Vibration Acceptance Tests", Ontario Hydro Research Division Report No 89-4-K, 1989.

3. N. Jagan, P. Hoogendam, "Darlington NGS 'A' Standby Generator #3 - Vibration Acceptance Tests", Ontario Hydro Research Division Report No 89-5-K, 1989.

4. "Type H Industrial Combustion Gas Turbines for Refinery Services", API Standard 616, 2nd Ed, June 1982.

TABLE 1
INSTRUMENTATION LIST

1. Accelerometer	Bruel & Kjaer Model 4368
2. Accelerometer	Endevco Model 7707-1000
3. Displacement Transducer	Bently Nevada Model 21505-00-12-60-02
4. Charge Amplifier	Bruel & Kjaer Model 2635
5. Displacement Transducer Amplifier	Ontario Hydro Research
6. Photoelectric Tachometer Probe	Bruel & Kjaer MM 0024
7. Dual Channel Analyzer	Ono Sokki CF 920
8. Digital Plotter	Hewlett-Packard Model 7470A
9. Laserjet Printer	Texas Instruments - Omnilaser 2108
10. Oscilloscope	Tektronix Model 2215
11. Tape Recorder	Honeywell Model 101
12. Filter	Krohn-Hite Model 3343
13. Vibration Calibrator	General Radio Model 1557-A
14. Digital Vector Filter	Bently Nevada DVF 2
15. Instrumented Tip Impact Hammer	PCB Piezotronics Inc, Model 086B50
16. Personal Microcomputer	IBM-PC AT

TABLE 2

DARLINGTON GS 'A' STANDBY GENERATOR #4
AC GENERATOR 1 x SYNCHRONOUS, 2 x SYNCHRONOUS AND OVERALL CASING VELOCITY LEVELS

	AC Generator Outboard Bearing Casing Velocity X - Direction				AC Generator Outboard Bearing Casing Velocity Y - Direction				AC Generator Outboard Bearing Casing Velocity Axial Direction			
Load (MW)	1 x Sync (60 Hz) mm/s pk	2 x Sync (120 Hz) mm/s pk	Overall RMS mm/s	Overall Peak mm/s pk	1 x Sync (60 Hz) mm/s pk	2 x Sync (120 Hz) mm/s pk	Overall RMS mm/s	Overall Peak mm/s pk	1 x Sync (60 Hz) mm/s pk	2 x Sync (120 Hz) mm/s pk	Overall RMS mm/s	Overall Peak mm/s pk
0	0.33	0.43	0.4	0.7	0.33	0.39	0.4	0.8	0.41	0.17	0.4	0.9-1.2
7	0.34	0.36	0.4	0.7	0.34	0.32	0.4	0.8	0.35	0.15	0.4	0.7-1.2
13	0.33	0.29	0.3	0.6	0.32	0.26	0.4	0.8	0.45	0.15	0.4	0.8
20	0.31	0.38	0.4	0.7	0.29	0.33	0.4	0.8	0.52	0.15	0.5	1.0-1.2
26	0.30	0.36	0.4	0.7	0.26	0.32	0.4	0.8	0.53	0.14	0.4-0.5	0.7-1.0

	AC Generator Inboard Bearing Casing Velocity X - Direction				AC Generator Inboard Bearing Casing Velocity Y - Direction				AC Generator Inboard Bearing Casing Velocity Axial Direction			
Load (MW)	1 x Sync (60 Hz) mm/s pk	2 x Sync (120 Hz) mm/s pk	Overall RMS mm/s	Overall Peak mm/s pk	1 x Sync (60 Hz) mm/s pk	2 x Sync (120 Hz) mm/s pk	Overall RMS mm/s	Overall Peak mm/s pk	1 x Sync (60 Hz) mm/s pk	2 x Sync (120 Hz) mm/s pk	Overall RMS mm/s	Overall Peak mm/s pk
0	0.19	0.02	0.2	0.5	0.42	0.41	0.4	0.9	0.09	0.17	0.3	0.5
7	0.25	0.22	0.3	0.5	0.43	0.23	0.4	0.8	0.06	0.15	0.3	0.5
13	0.32	0.42	0.4	0.8	0.44	0.11	0.4	0.8	0.11	0.07	0.2	0.5
20	0.37	0.31	0.4	0.8	0.48	0.23	0.5	1.1	0.14	0.03	0.3	0.7
26	0.36	0.28	0.4	0.7	0.47	0.21	0.5	1.0-1.3	0.12	0.03	0.3	0.6

TABLE 3

DARLINGTON GS 'A' STANDBY GENERATOR #4
POWER TURBINE 1 x SYNCHRONOUS, 2 x SYNCHRONOUS AND OVERALL CASING VELOCITY LEVELS

	Power Turbine Inboard Bearing Casing Velocity X - Direction				Power Turbine Inboard Bearing Casing Velocity Y - Direction				Power Turbine Inboard Bearing Casing Velocity Axial Direction			
Load (MW)	1 x Sync (60 Hz) mm/s pk	2 x Sync (120 Hz) mm/s pk	Overall RMS mm/s	Overall Peak mm/s pk	1 x Sync (60 Hz) mm/s pk	2 x Sync (120 Hz) mm/s pk	Overall RMS mm/s	Overall Peak mm/s pk	1 x Sync (60 Hz) mm/s pk	2 x Sync (120 Hz) mm/s pk	Overall RMS mm/s	Overall Peak mm/s pk
0	1.75	0.05	1.4-1.9	2.5-4.7	1.91	0.18	1.4-1.8	2.5-3.6	0.63	0.06	1.2-1.9	1.6-4.7
7	1.01	0.05	1.2-1.6	2.0-4.0	0.56	0.22	0.9-1.1	1.5-2.0	0.75	0.07	1.2-2.0	2.2-4.6
13	1.76	0.07	1.5-1.7	2.5-3.9	1.59	0.24	1.3-1.5	1.9-3.4	0.79	0.12	1.3-1.6	2.8-4.3
20	2.30	0.17	1.7-2.0	2.9-4.2	2.36	0.21	1.7-1.9	3.6-4.4	0.73	0.16	1.0-1.6	3.1-4.2
26	2.17	0.16	1.6-1.9	2.9-3.9	2.56	0.19	1.8-2.0	3.1-3.9	0.64	0.17	1.1-2.0	2.2-4.0

	Power Turbine Outboard Bearing Casing (Pedestal) Velocity Horizontal Direction				Power Turbine Outboard Bearing Casing (Pedestal) Velocity Vertical Direction				Power Turbine Outboard Bearing Casing (Pedestal) Velocity Axial Direction			
Load (MW)	1 x Sync (60 Hz) mm/s pk	2 x Sync (120 Hz) mm/s pk	Overall RMS mm/s	Overall Peak mm/s pk	1 x Sync (60 Hz) mm/s pk	2 x Sync (120 Hz) mm/s pk	Overall RMS mm/s	Overall Peak mm/s pk	1 x Sync (60 Hz) mm/s pk	2 x Sync (120 Hz) mm/s pk	Overall RMS mm/s	Overall Peak mm/s pk
0	2.31	0.47	1.8-2.8	3.8-6.1	3.91	0.68	3.5-4.8	7.9-9.6	0.70	0.08	1.4-1.8	2.1-3.8
7	2.23	0.48	2.1-2.7	3.1-6.0	3.19	0.75	2.9-4.0	5.0-10.0	0.70	0.18	1.5-2.3	1.6-4.1
13	2.32	0.43	2.0-2.5	4.1-5.8	2.76	0.80	2.5-3.3	4.9-7.6	0.64	0.19	1.3-2.0	3.2-4.2
20	2.18	0.55	2.1-2.3	3.6-6.2	2.63	0.88	2.5-3.4	5.0-8.2	0.54	0.17	1.2-1.8	2.7-3.9
27	2.13	0.62	1.7-2.3	3.9-6.8	2.59	0.92	2.4-3.5	5.6-7.3	0.49	0.15	1.5-2.0	2.2-3.8

TABLE 4

DARLINGTON GS 'A' STANDBY GENERATOR #4

AC GENERATOR 1 x SYNCHRONOUS, 2 x SYNCHRONOUS, AND OVERALL SHAFT RELATIVE DISPLACEMENT LEVELS

Load (MW)	AC Generator Outboard Bearing Shaft Displacement X - Direction (μm p-p)			AC Generator Outboard Bearing Shaft Displacement Y - Direction (μm p-p)			AC Generator Inboard Bearing Shaft Displacement X - Direction (μm p-p)			AC Generator Inboard Bearing Shaft Displacement Y - Direction (μm p-p)		
	1 x Sync (60 Hz)	2 x Sync (120 Hz)	Overall	1 x Sync (60 Hz)	2 x Sync (120 Hz)	Overall	1 x Sync (60 Hz)	2 x Sync (120 Hz)	Overall	1 x Sync (60 Hz)	2 x Sync (120 Hz)	Overall
0	8.2	2.7	14	13.1	3.5	17	7.3	3.5	19	5.8	1.6	14
7	8.7	2.5	13	13.4	3.4	17	8.1	3.7	20	7.1	1.3	14
13	8.5	2.3	13	12.4	3.1	18	8.8	4.0	21	7.8	0.8	13
20	8.2	2.5	13	11.1	3.1	15	9.5	4.0	20	8.4	0.8	14
26	8.0	2.5	13	10.4	3.1	16	9.6	3.7	21	7.9	0.7	13

TABLE 5

DARLINGTON GS 'A' STANDBY GENERATOR #4
POWER TURBINE 1 x SYNCHRONOUS, 2 x SYNCHRONOUS, AND OVERALL SHAFT RELATIVE DISPLACEMENT LEVELS

	Power Turbine Inboard Bearing Shaft Displacement X - Direction (μm p-p)			Power Turbine Inboard Bearing Shaft Displacement Y - Direction (μm p-p)			Power Turbine Outboard Bearing Shaft Displacement X - Direction (μm p-p)			Power Turbine Outboard Bearing Shaft Displacement Y - Direction (μm p-p)		
Load (MW)	1 x Sync (60 Hz)	2 x Sync (120 Hz)	Overall	1 x Sync (60 Hz)	2 x Sync (120 Hz)	Overall	1 x Sync (60 Hz)	2 x Sync (120 Hz)	Overall	1 x Sync (60 Hz)	2 x Sync (120 Hz)	Overall
0	32.2	4.7	40 - 48	43.8	6.0	60 - 80	8.5	3.7	15 - 24	41.5	4.5	45 - 72
7	40.8	4.8	47 - 56	50.8	6.5	63 - 73	8.1	3.4	17 - 22	33.2	4.9	39 - 55
13	40.5	5.4	48 - 52	51.0	6.6	54 - 64	7.7	3.4	11 - 16	28.2	4.9	35 - 58
20	34.8	6.4	37 - 43	42.7	6.2	48 - 54	6.5	3.8	11 - 17	28.0	5.4	41 - 56
26	30.0	6.6	31 - 40	35.5	6.3	45 - 52	5.7	4.0	11 - 17	29.8	5.8	43 - 56

TABLE 6

DARLINGTON GS 'A' STANDBY GENERATOR #4 - AC GENERATOR
FIGURE NUMBERS OF VIBRATION SPECTRA, BODE PLOTS AND RPM SPECTRAL MAPS

Measurement		FFT Spectrum Figure No. Load (MW) 0	7	13	20	26	Bode Plot Cold Start Runup Figure No.	Bode Plot Hot Start Runup Figure No.	RPM Spectral Map Hot Start Runup Figure No.	Bode Plot Rundown from Overspeed Figure No.	RPM Spectral Map Rundown from Overspeed Figure No.
Outboard Bearing Casing Velocity	X - Direction	7	13	19	25	31	107	127	147	167	187
	Y - Direction	8	14	20	26	32	108	128	148	168	188
	Axial	9	15	21	27	33	109	129	149	169	189
Inboard Bearing Casing Velocity	X - Direction	10	16	22	28	34	110	130	150	170	190
	Y - Direction	11	17	23	29	35	111	131	151	171	191
	Axial	12	18	24	30	36	112	132	152	172	192
Outboard Bearing Shaft Displacement	X - Direction	67	71	75	79	83	113	133	153	173	193
	Y - Direction	68	72	76	80	84	114	134	154	174	194
Inboard Bearing Shaft Displacement	X - Direction	69	73	77	81	85	115	135	155	175	195
	Y - Direction	70	74	78	82	86	116	136	156	176	196

TABLE 7

DARLINGTON GS 'A' STANDBY GENERATOR #4 - POWER TURBINE
FIGURE NUMBERS OF VIBRATION SPECTRA, BODE PLOTS AND RPM SPECTRAL MAPS

Measurement		FFT Spectrum Figure No. Load (MW) 0	7	13	20	26	Bode Plot Cold Start Runup Figure No.	Bode Plot Hot Start Runup Figure No.	RPM Spectral Map Hot Start Runup Figure No.	Bode Plot Rundown from Overspeed Figure No.	RPM Spectral Map Rundown from Overspeed Figure No.
Inboard Bearing Casing Velocity	X - Direction	37	43	49	55	61	117	137	157	177	197
	Y - Direction	38	44	50	56	62	118	138	158	178	198
	Axial	39	45	51	57	63	119	139	159	179	199
Outboard Bearing Casing (Pedestal) Velocity	Horizontal	40	46	52	58	64	120	140	160	180	200
	Vertical	41	47	53	59	65	121	141	161	181	201
	Axial	42	48	54	60	66	122	142	162	182	202
Inboard Bearing Shaft Displacement	X - Direction	87	91	95	99	103	123	143	163	183	203
	Y - Direction	88	92	96	100	104	124	144	164	184	204
Outboard Bearing Shaft Displacement	X - Direction	89	93	97	101	105	125	145	165	185	205
	Y - Direction	90	94	98	102	106	126	146	166	186	206

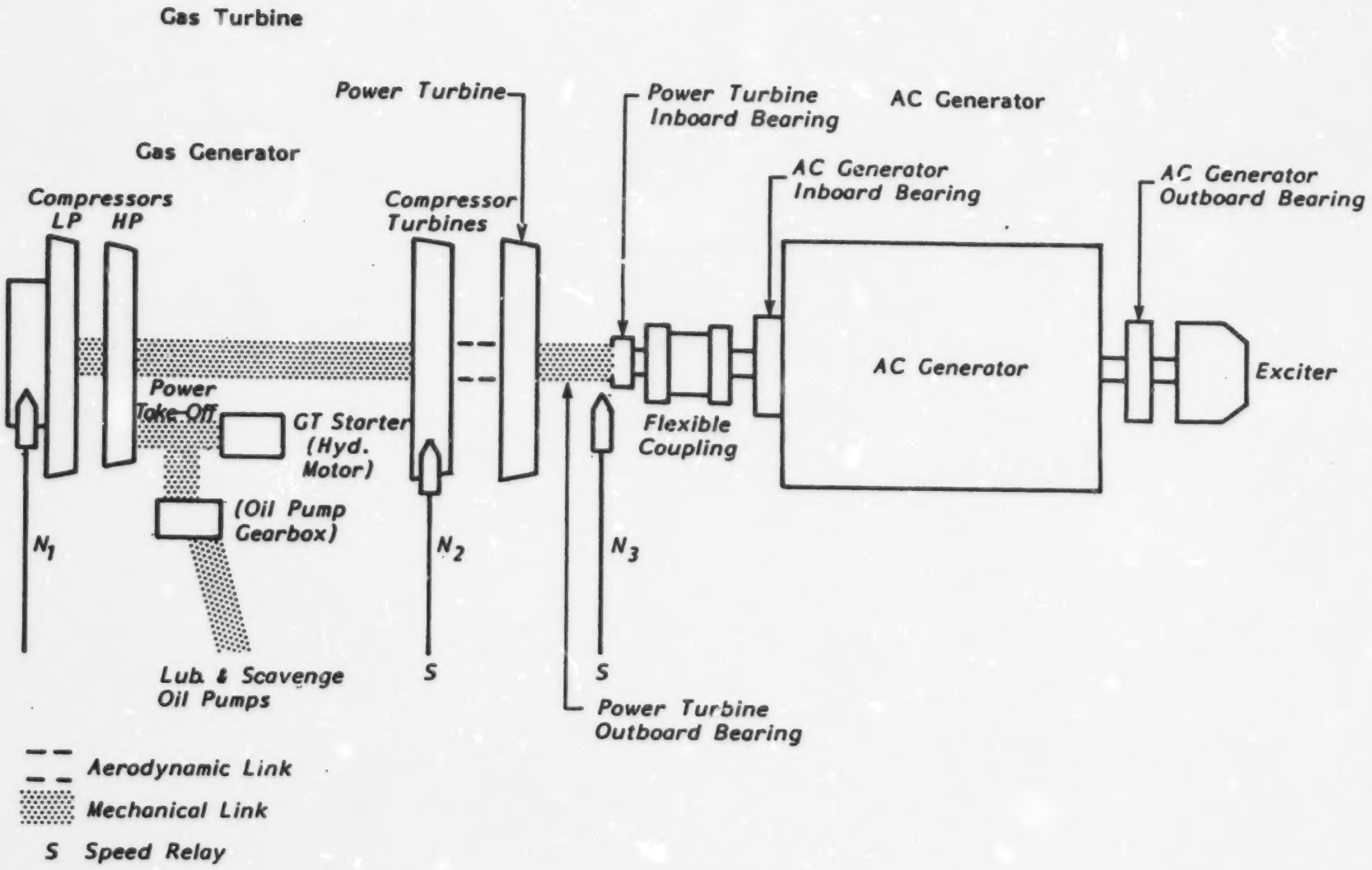


FIGURE 1

DARLINGTON NGS STANDY TURBINE-GENERATOR SYSTEM

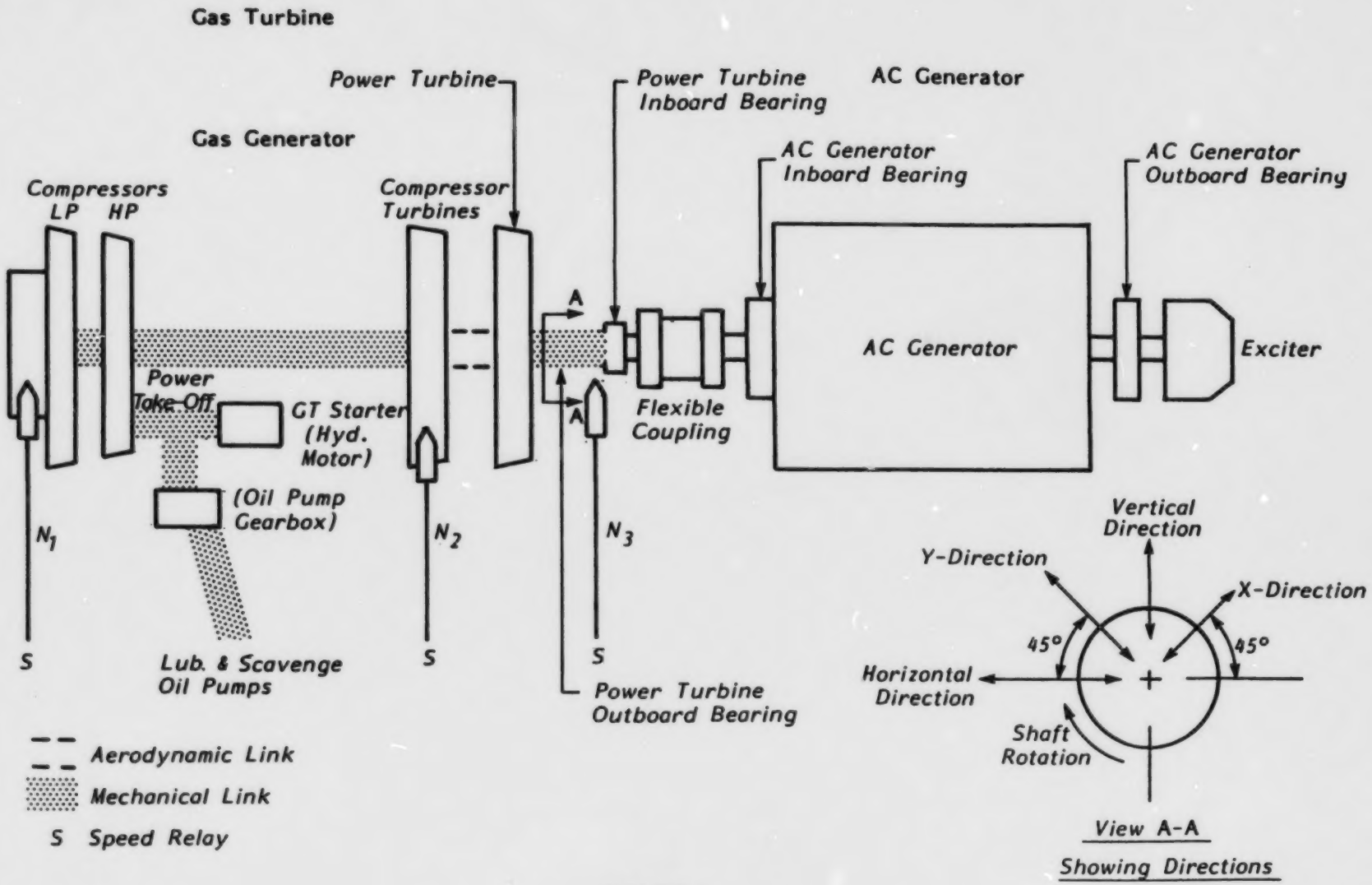
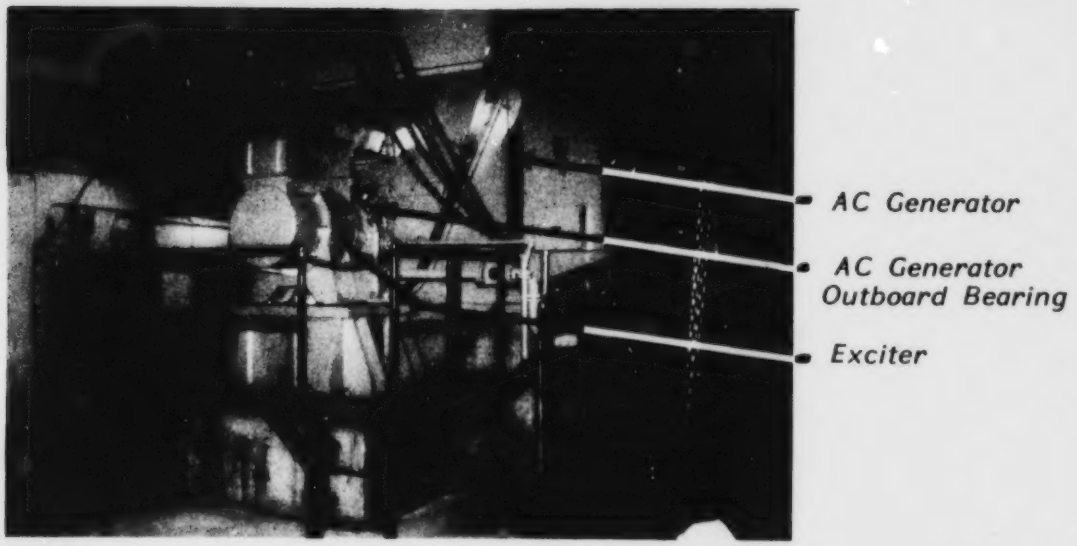
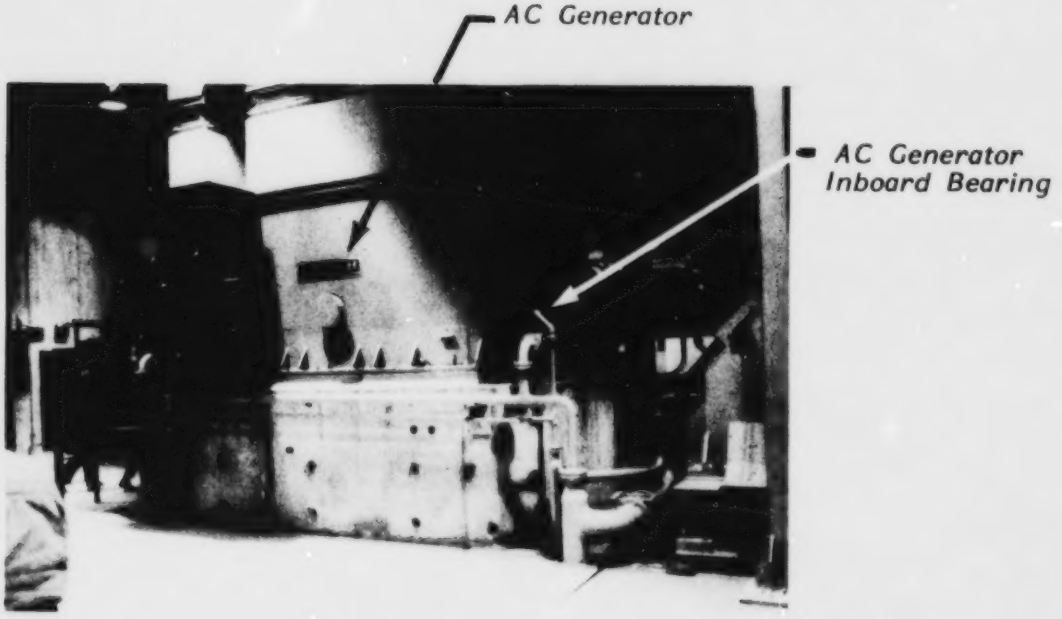


FIGURE 2

DARLINGTON NGS STANDBY TURBINE-GENERATOR SYSTEM
SHOWING MEASUREMENT DIRECTIONS

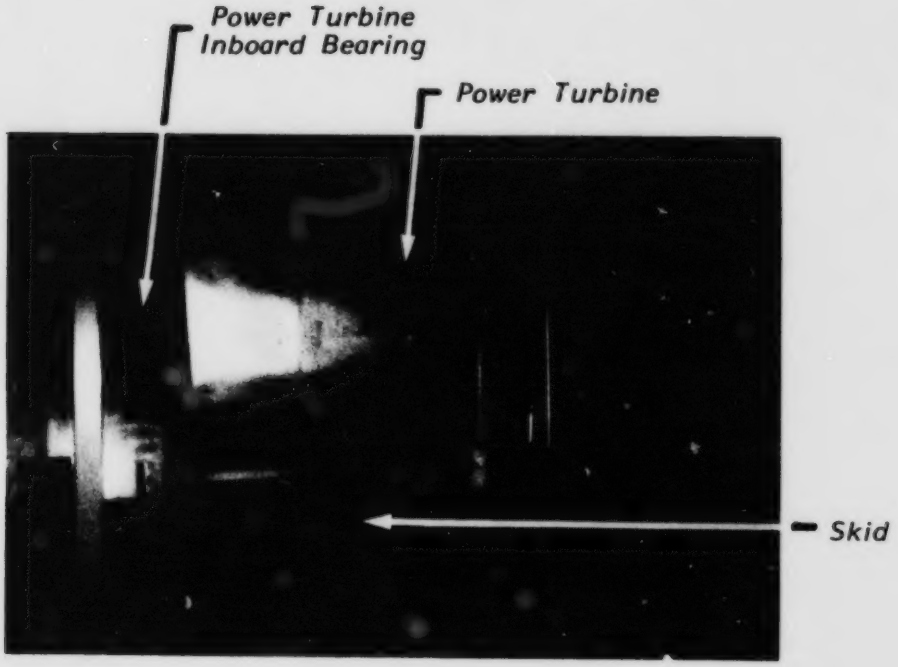


(a)



(b)

FIGURES 3(a) & (b)
LAYOUT OF STANDBY GENERATOR SYSTEM



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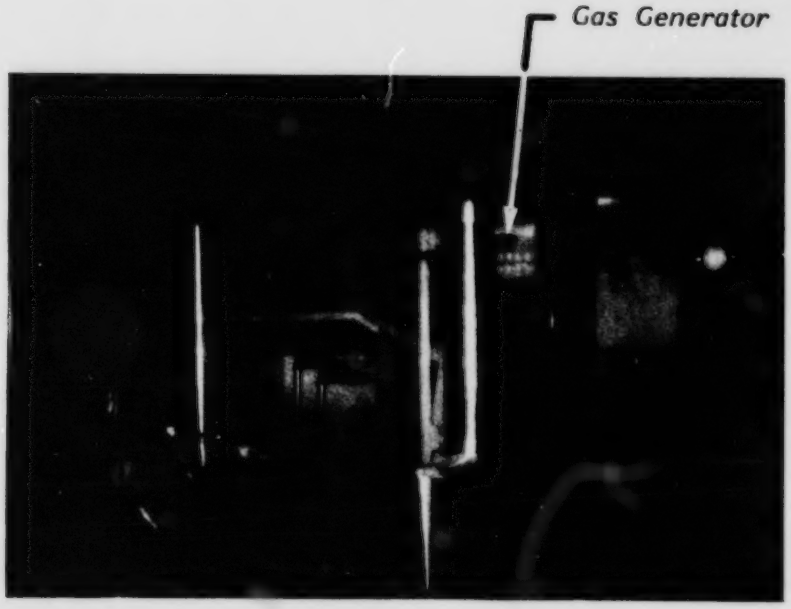
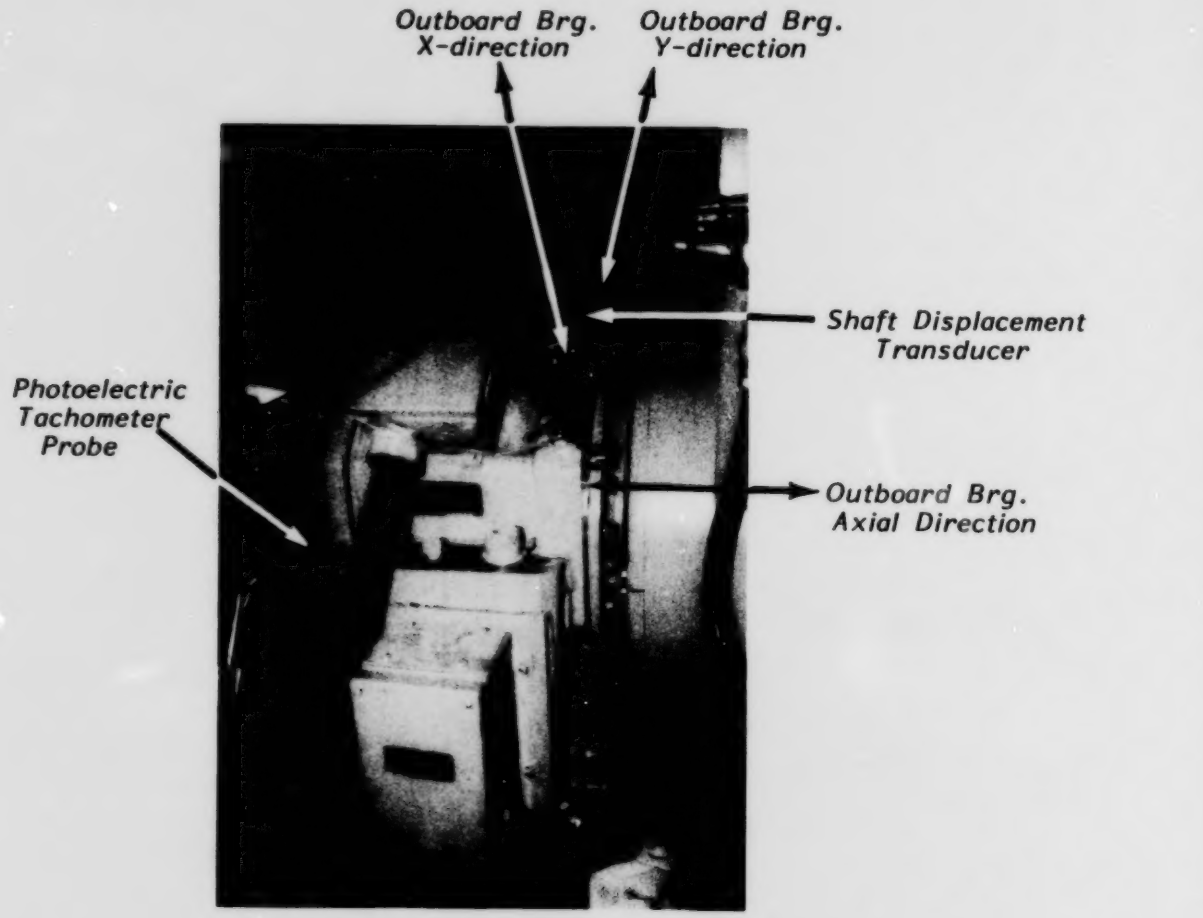


(d)

FIGURES 3(c) & (d)
LAYOUT OF STANDBY GENERATOR SYSTEM



(a) AC Generator Outboard Bearing

(b) AC Generator Inboard Bearing

FIGURE 4
LOCATION AND DIRECTION OF TRANSDUCERS ON AC GENERATOR BEARINGS

177141-RD

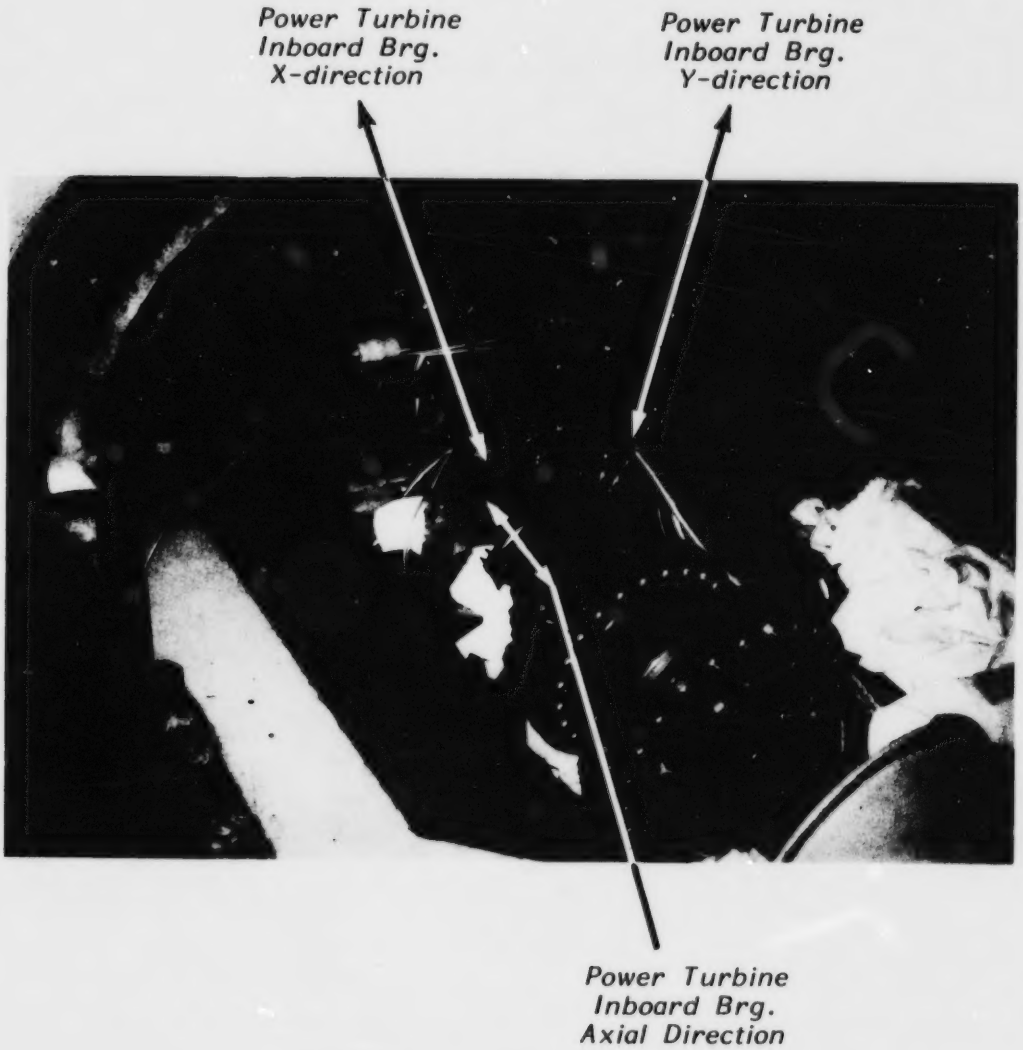


FIGURE 5

POWER TURBINE INBOARD BEARING
MEASUREMENT LOCATIONS

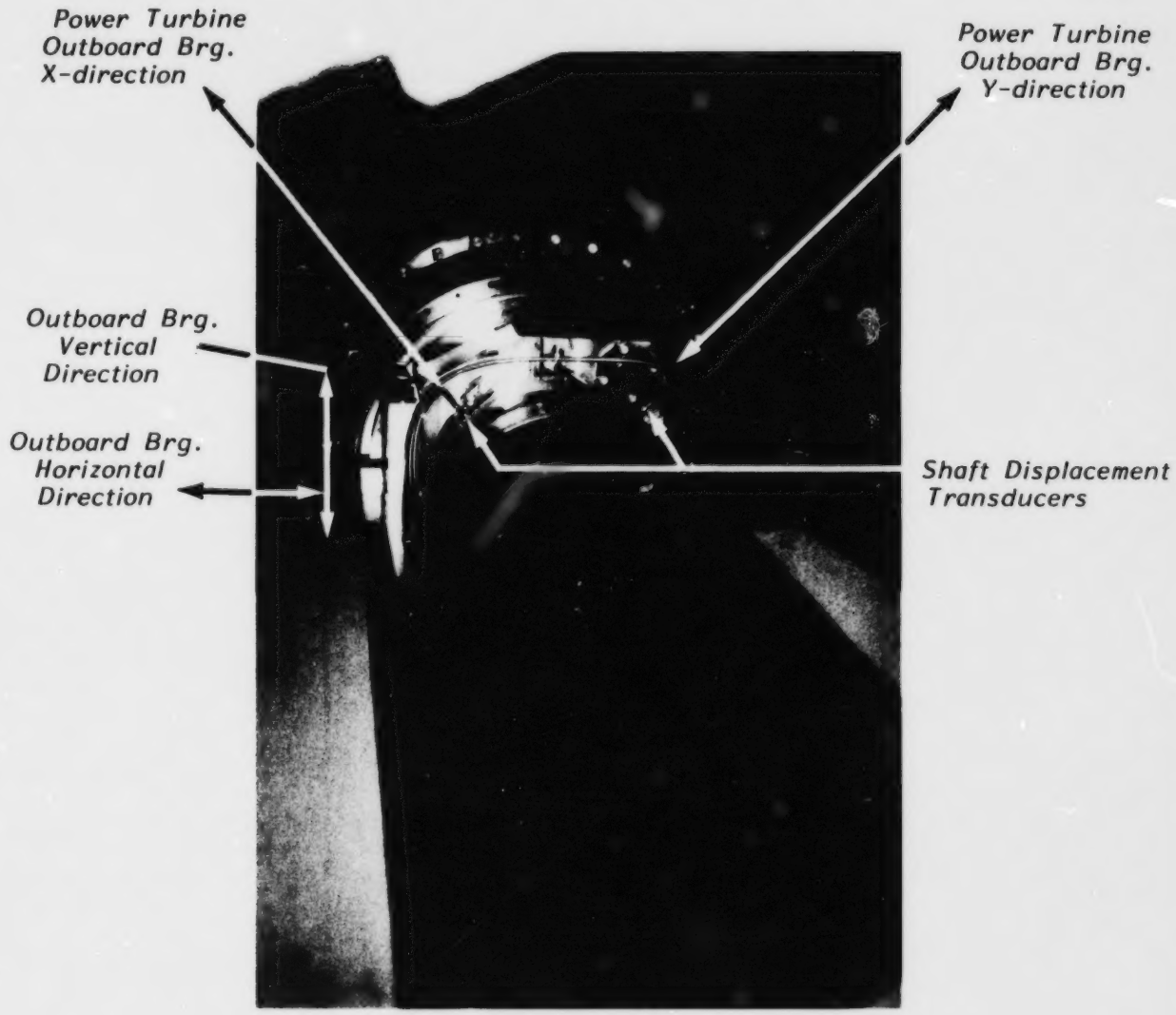


FIGURE 6

POWER TURBINE OUTBOARD BEARING
MEASUREMENT LOCATIONS

177143-RD

Darlington GS Standby Generator #4 AC Generator

SIGNAL : Outboard Brg. Casing Velocity X-Axis
SPEED : 3600 r.p.m.
PROCESS CONDITION : Load 0 MW

PEAK NO.	FREQUENCY	ORDER	AMPLITUDE
1	120.0	2.00	0.43
2	60.0	1.00	0.33
3	180.0	3.00	0.14
4	240.0	4.00	0.07
5	540.0	9.00	0.02
6	86.5	1.44	0.02
7	19.5	0.33	0.02
8	92.1	1.53	0.02
9	480.0	8.00	0.02
10	23.7	0.40	0.02

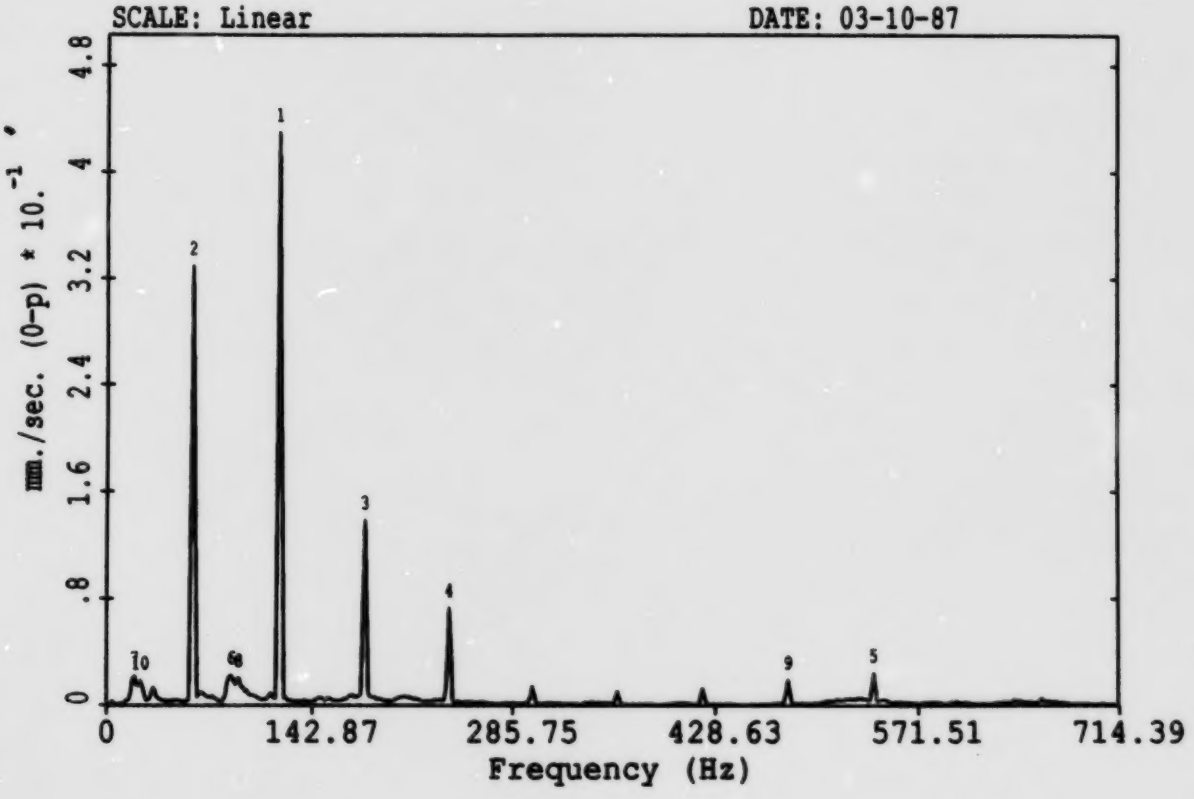


FIGURE 7

Darlington GS Standby Generator #4 AC Generator

SIGNAL : Outboard Brg. Casing Velocity Y-Axis
SPEED : 3600 r.p.m.
PROCESS CONDITION : Load 0 MW

PEAK NO.	FREQUENCY	ORDER	AMPLITUDE
1	120.0	2.00	0.39
2	60.0	1.00	0.33
3	180.0	3.00	0.19
4	300.0	5.00	0.11
5	85.1	1.42	0.03
6	90.7	1.51	0.03
7	420.0	7.00	0.02
8	360.0	6.00	0.02
9	23.7	0.40	0.02
10	240.0	4.00	0.02

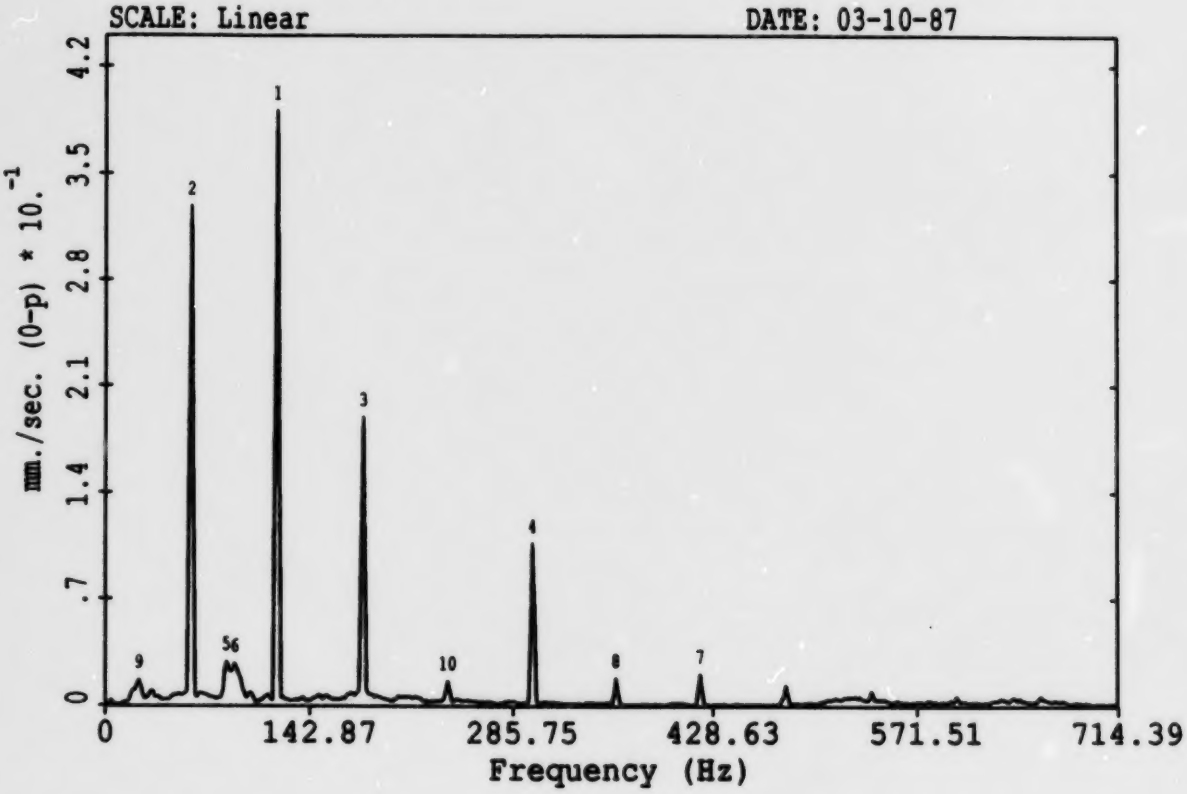


FIGURE 8

Darlington GS Standby Generator #4 AC Generator

SIGNAL : Outboard Brg. Casing Velocity Axial
SPEED : 3600 r.p.m.
PROCESS CONDITION : Load 0 MW

PEAK NO.	FREQUENCY	ORDER	AMPLITUDE
1	60.0	1.00	0.41
2	85.1	1.42	0.21
3	120.0	2.00	0.17
4	300.0	5.00	0.10
5	100.5	1.67	0.04
6	97.7	1.63	0.03
7	64.2	1.07	0.03
8	240.0	4.00	0.02
9	23.7	0.40	0.02
10	360.0	6.00	0.02

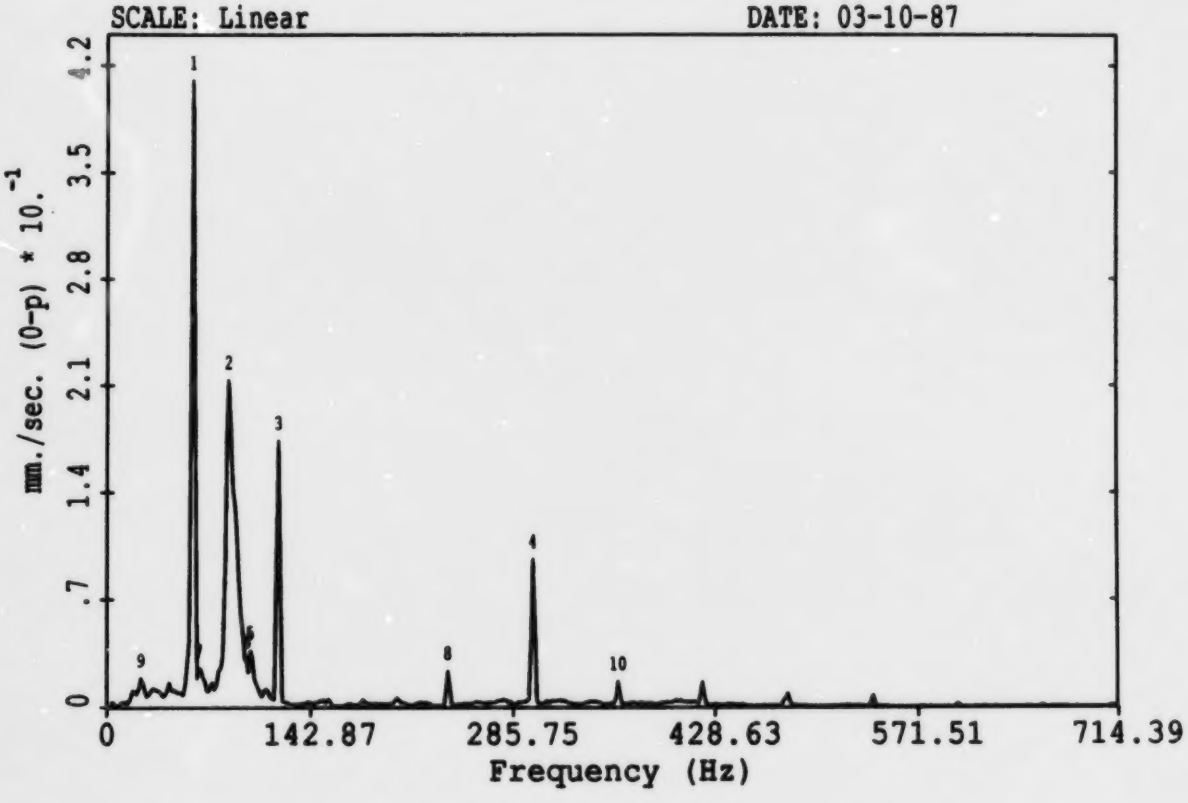


FIGURE 9

Darlington GS Standby Generator #4 AC Generator

SIGNAL : Inboard Brg. Casing Velocity X-Axis
SPEED : 3600 r.p.m.
PROCESS CONDITION : Load 0 MW

PEAK NO.	FREQUENCY	ORDER	AMPLITUDE
1	60.0	1.00	0.19
2	240.0	4.00	0.11
3	180.0	3.00	0.05
4	300.0	5.00	0.04
5	360.0	6.00	0.03
6	18.1	0.30	0.03
7	23.7	0.40	0.03
8	480.0	8.00	0.03
9	82.3	1.37	0.03
10	120.0	2.00	0.02

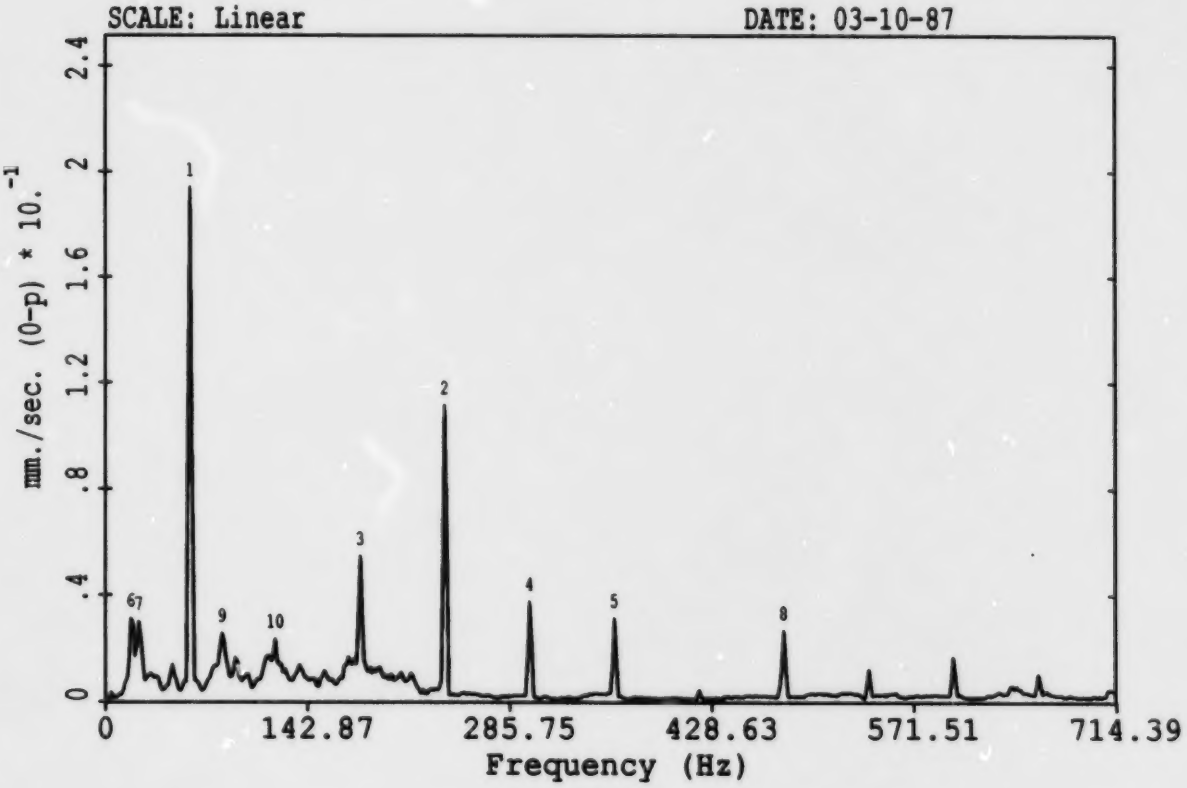


FIGURE 10

Darlington GS Standby Generator #4 AC Generator

SIGNAL : Inboard Brg. Casing Velocity Y-Axis
SPEED : 3600 r.p.m.
PROCESS CONDITION : Load 0 MW

PEAK NO.	FREQUENCY	ORDER	AMPLITUDE
1	60.0	1.00	0.42
2	120.0	2.00	0.41
3	240.0	4.00	0.12
4	300.0	5.00	0.07
5	180.0	3.00	0.04
6	360.0	6.00	0.03
7	216.3	3.60	0.02
8	209.3	3.49	0.02
9	171.6	2.86	0.02
10	23.7	0.40	0.02

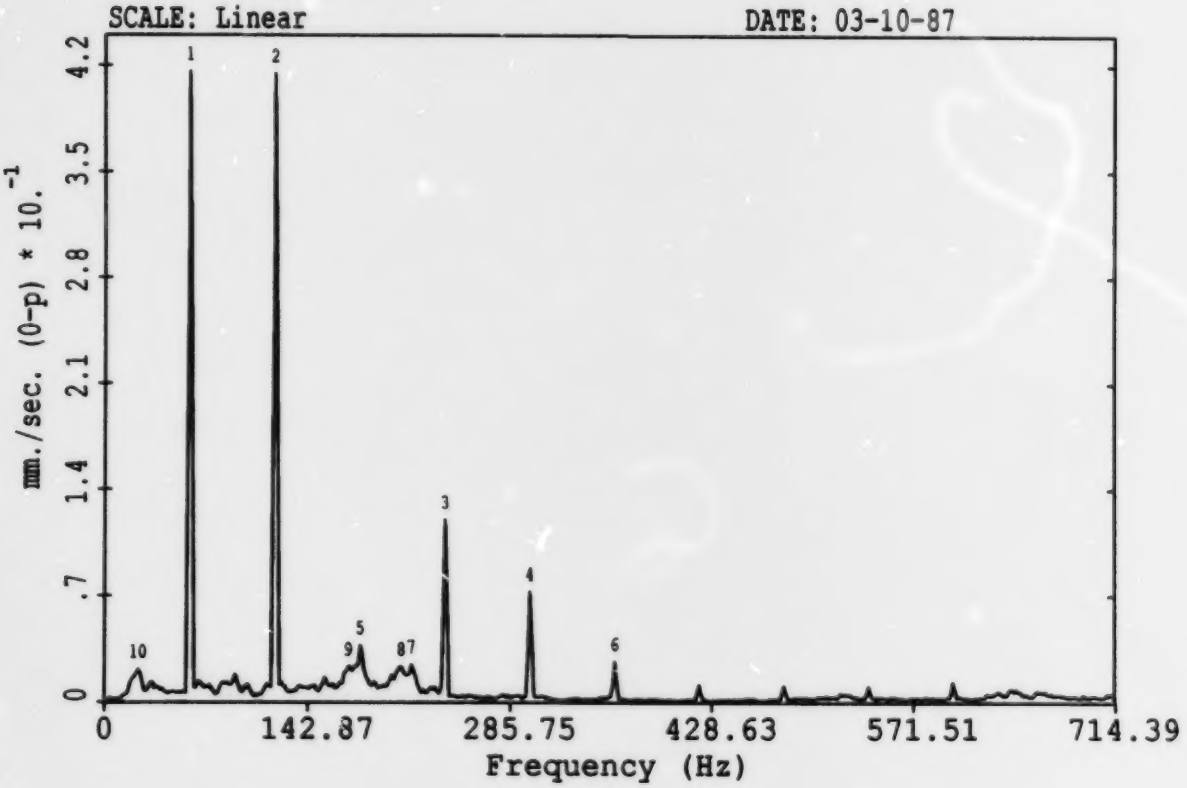


FIGURE 11

Darlington GS Standby Generator #4 AC Generator

SIGNAL : Inboard Brg. Casing Velocity Axial
SPEED : 3600 r.p.m.
PROCESS CONDITION : Load 0 MW

PEAK NO.	FREQUENCY	ORDER	AMPLITUDE
1	120.0	2.00	0.17
2	82.3	1.37	0.12
3	60.0	1.00	0.09
4	92.1	1.53	0.06
5	300.0	5.00	0.05
6	240.0	4.00	0.05
7	100.5	1.67	0.04
8	180.0	3.00	0.02
9	65.6	1.09	0.02
10	23.7	0.40	0.02

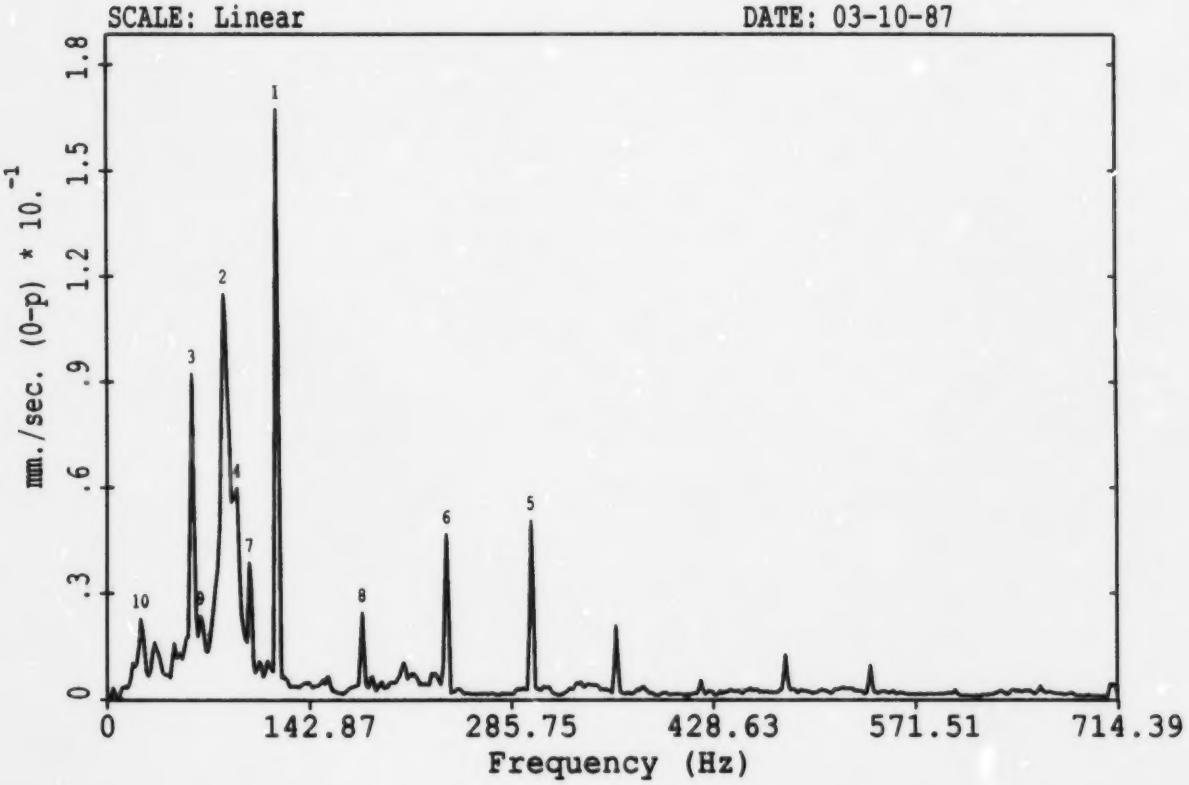


FIGURE 12

Darlington GS Standby Generator #4 AC Generator

SIGNAL : Outboard Brg. Casing Velocity X-Axis
SPEED : 3600 r.p.m.
PROCESS CONDITION : Load 7 MW

PEAK NO.	FREQUENCY	ORDER	AMPLITUDE
1	120.0	2.00	0.36
2	60.0	1.00	0.34
3	180.0	3.00	0.14
4	240.0	4.00	0.06
5	87.9	1.47	0.03
6	90.7	1.51	0.03
7	540.0	9.00	0.03
8	300.0	5.00	0.02
9	480.0	8.00	0.02
10	23.7	0.40	0.02

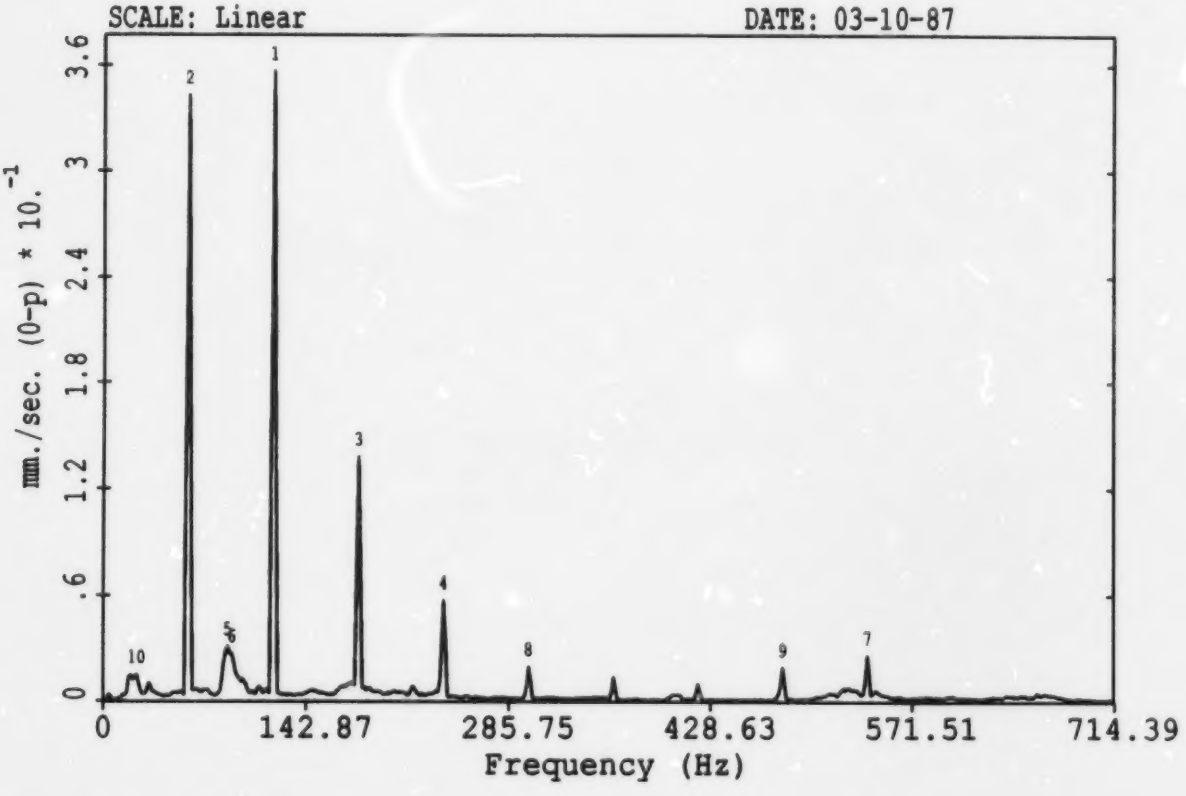


FIGURE 13

Darlington GS Standby Generator #4 AC Generator

SIGNAL : Outboard Brg. Casing Velocity Y-Axis
SPEED : 3600 r.p.m.
PROCESS CONDITION : Load 7 MW

PEAK NO.	FREQUENCY	ORDER	AMPLITUDE
1	60.0	1.00	0.34
2	120.0	2.00	0.32
3	180.0	3.00	0.19
4	300.0	5.00	0.11
5	86.5	1.44	0.04
6	90.7	1.51	0.03
7	420.0	7.00	0.02
8	22.3	0.37	0.02
9	240.0	4.00	0.01
10	480.0	8.00	0.01

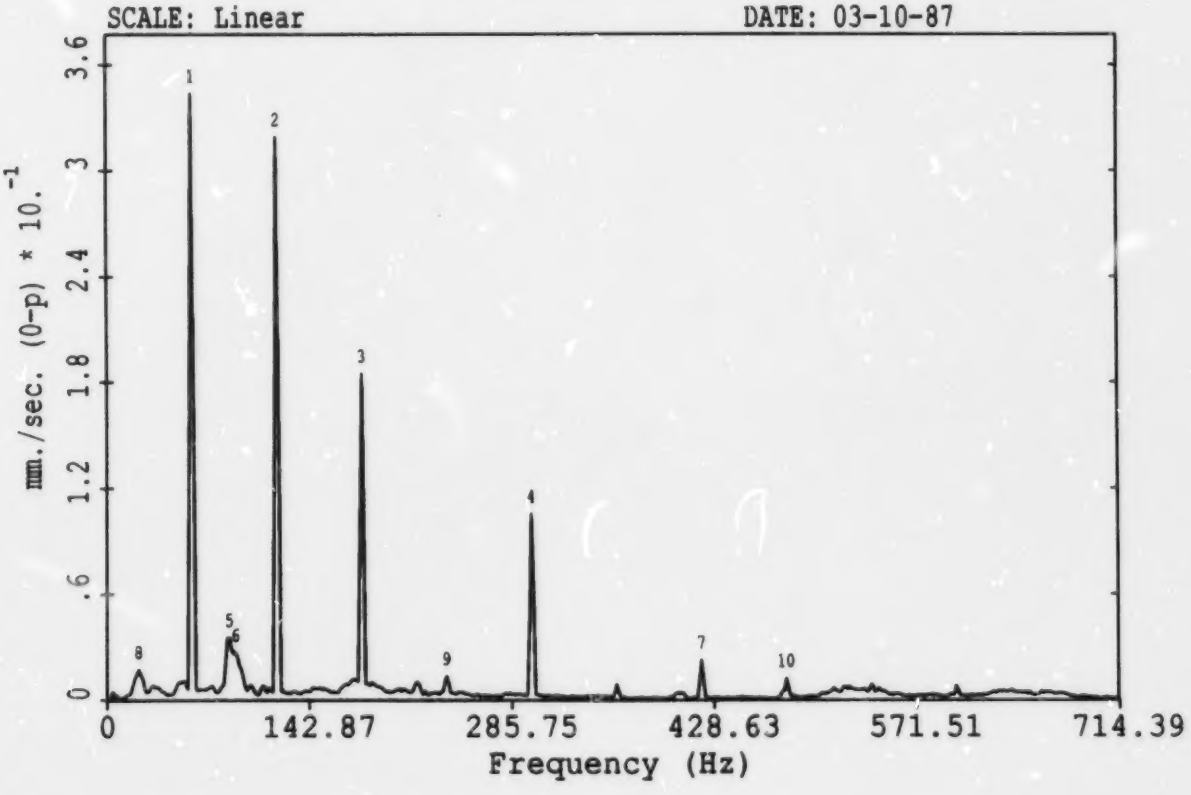


FIGURE 14

Darlington GS Standby Generator #4 AC Generator

SIGNAL : Outboard Brg. Casing Velocity Axial
SPEED : 3600 r.p.m.
PROCESS CONDITION : Load 7 MW

PEAK NO.	FREQUENCY	ORDER	AMPLITUDE
1	60.0	1.00	0.35
2	85.1	1.42	0.24
3	120.0	2.00	0.15
4	300.0	5.00	0.10
5	100.5	1.67	0.03
6	360.0	6.00	0.03
7	65.6	1.09	0.02
8	240.0	4.00	0.02
9	110.2	1.84	0.02
10	43.3	0.72	0.02

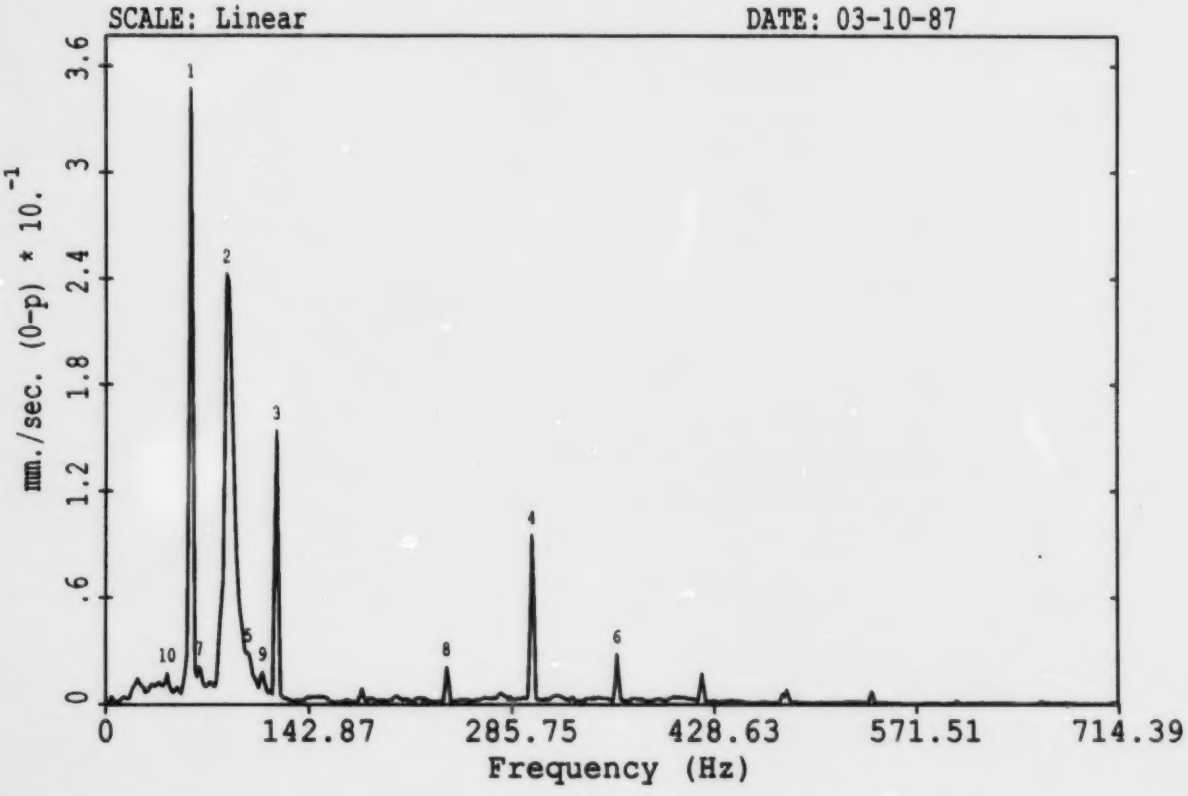


FIGURE 15

Darlington GS Standby Generator #4 AC Generator

SIGNAL : Inboard Brg. Casing Velocity X-Axis
SPEED : 3600 r.p.m.
PROCESS CONDITION : Load 7 MW

PEAK NO.	FREQUENCY	ORDER	AMPLITUDE
1	60.0	1.00	0.25
2	120.0	2.00	0.22
3	180.0	3.00	0.07
4	360.0	6.00	0.06
5	240.0	4.00	0.05
6	300.0	5.00	0.03
7	480.0	8.00	0.03
8	22.3	0.37	0.03
9	173.0	2.88	0.02
10	82.3	1.37	0.02

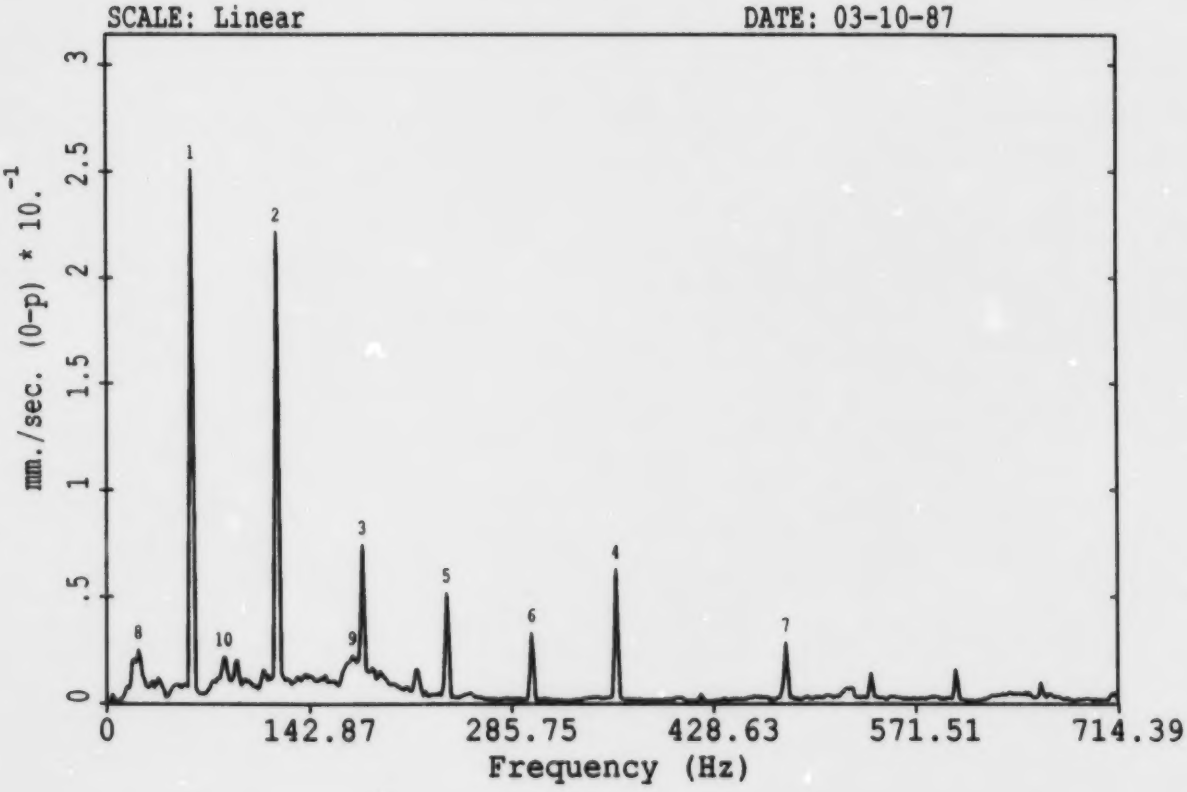


FIGURE 16

Darlington GS Standby Generator #4 AC Generator

SIGNAL : Inboard Brg. Casing Velocity Y-Axis
SPEED : 3600 r.p.m.
PROCESS CONDITION : Load 7 MW

PEAK NO.	FREQUENCY	ORDER	AMPLITUDE
1	60.0	1.00	0.43
2	120.0	2.00	0.23
3	180.0	3.00	0.09
4	360.0	6.00	0.07
5	300.0	5.00	0.06
6	219.1	3.65	0.04
7	173.0	2.88	0.03
8	238.6	3.98	0.03
9	22.3	0.37	0.02
10	90.7	1.51	0.02

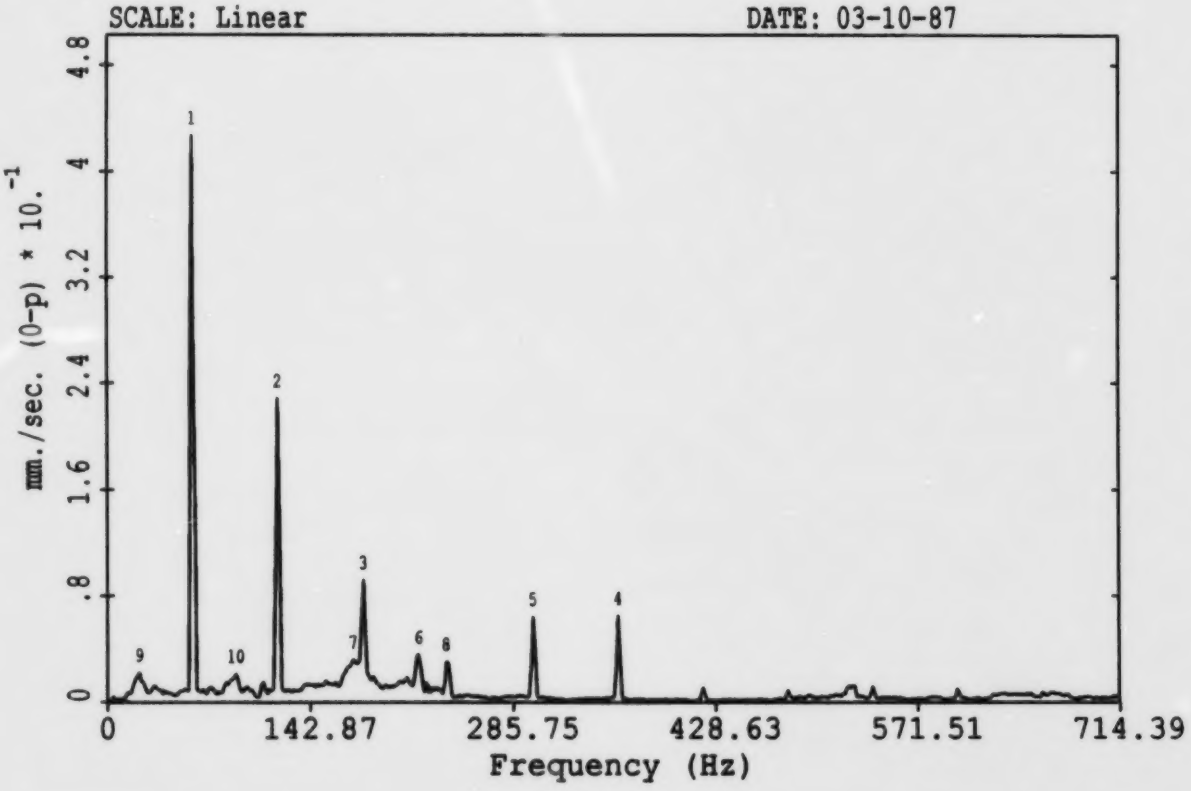


FIGURE 17

Darlington GS Standby Generator #4 AC Generator

SIGNAL : Inboard Brg. Casing Velocity Axial
SPEED : 3600 r.p.m.
PROCESS CONDITION : Load 7 MW

PEAK NO.	FREQUENCY	ORDER	AMPLITUDE
1	120.0	2.00	0.15
2	83.7	1.40	0.11
3	90.7	1.51	0.09
4	60.0	1.00	0.06
5	300.0	5.00	0.05
6	180.0	3.00	0.04
7	75.3	1.26	0.03
8	101.9	1.70	0.02
9	54.4	0.91	0.02
10	22.3	0.37	0.02

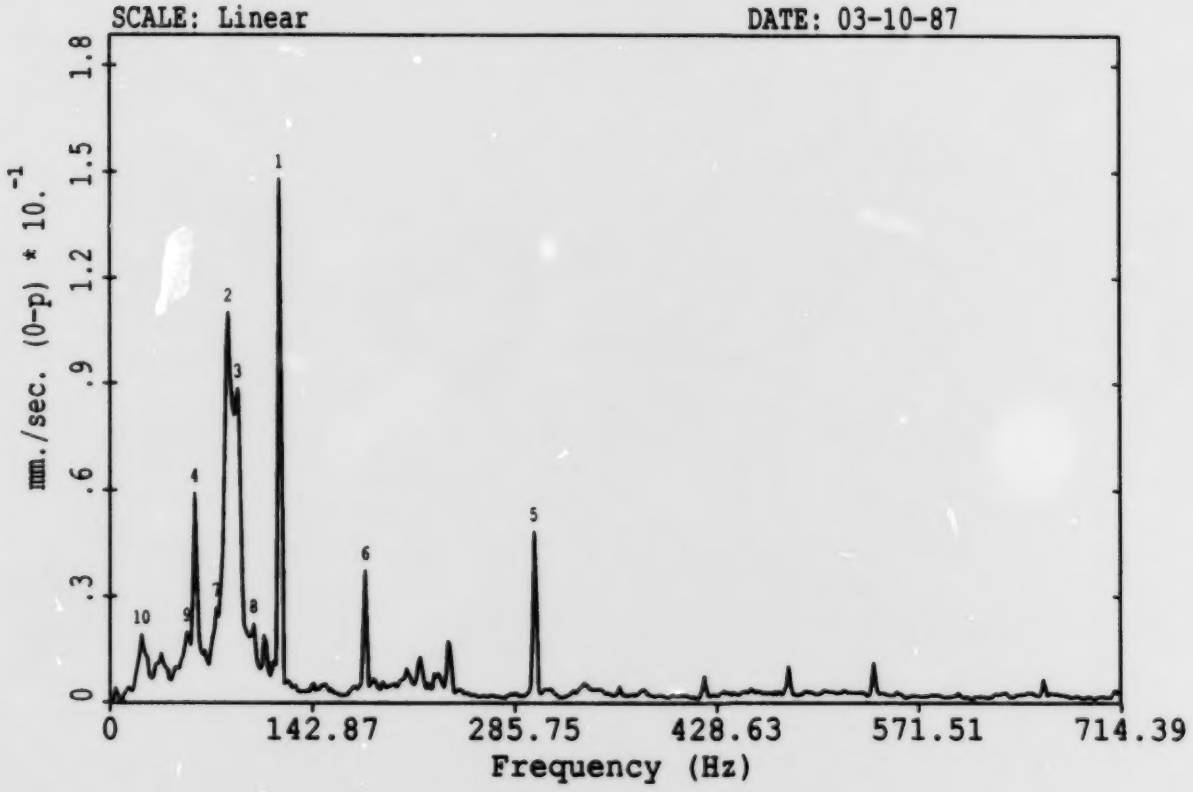


FIGURE 18

Darlington GS Standby Generator #4 AC Generator

SIGNAL : Outboard Brg. Casing Velocity X-Axis
SPEED : 3600 r.p.m.
PROCESS CONDITION : Load 13 MW

PEAK NO.	FREQUENCY	ORDER	AMPLITUDE
1	60.0	1.00	0.33
2	120.0	2.00	0.29
3	180.0	3.00	0.15
4	240.0	4.00	0.03
5	540.0	9.00	0.03
6	90.7	1.51	0.03
7	86.5	1.44	0.02
8	300.0	5.00	0.02
9	480.0	8.00	0.02
10	19.5	0.33	0.01

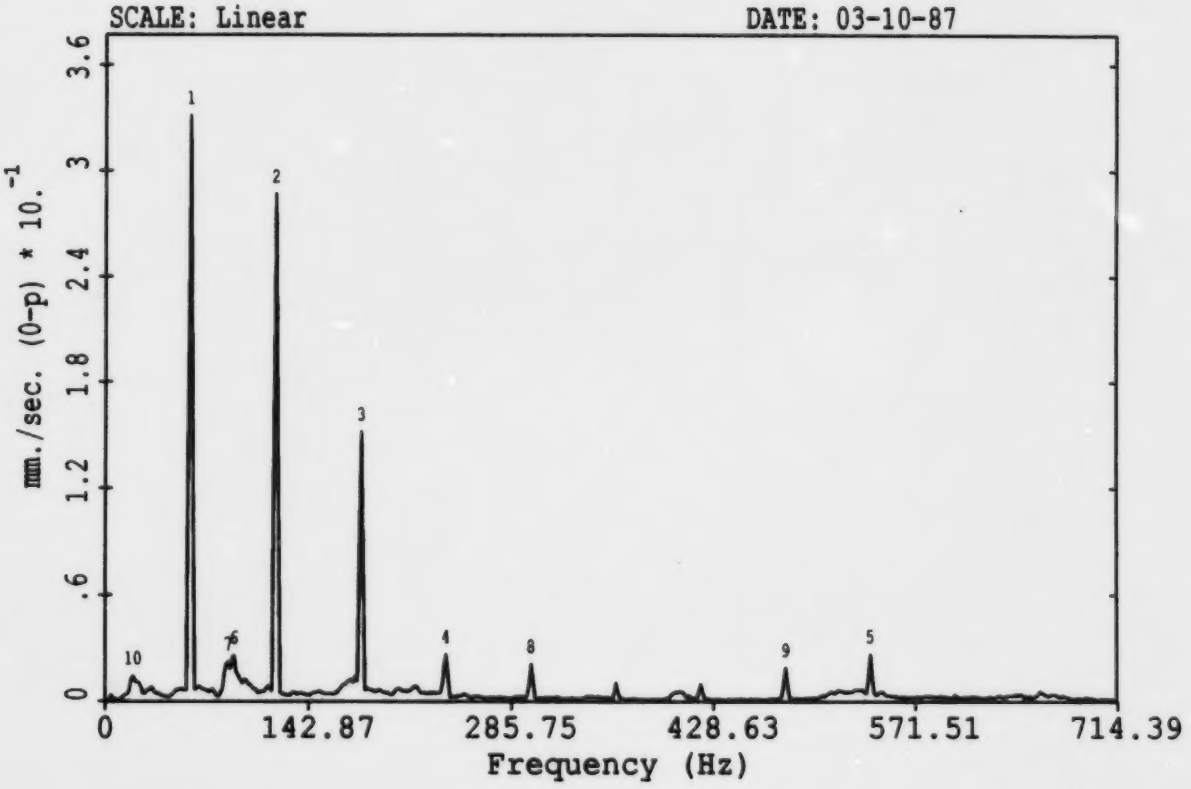


FIGURE 19

Darlington GS Standby Generator #4 AC Generator

SIGNAL : Outboard Brg. Casing Velocity Y-Axis
SPEED : 3600 r.p.m.
PROCESS CONDITION : Load 13 MW

PEAK NO.	FREQUENCY	ORDER	AMPLITUDE
1	60.0	1.00	0.32
2	120.0	2.00	[illegible]
3	180.0	3.00	0.20
4	300.0	5.00	[illegible]
5	240.0	4.00	0.07
6	85.1	1.42	0.03
7	90.7	1.51	0.03
8	93.5	1.56	0.03
9	420.0	7.00	0.02
10	22.3	0.37	0.02

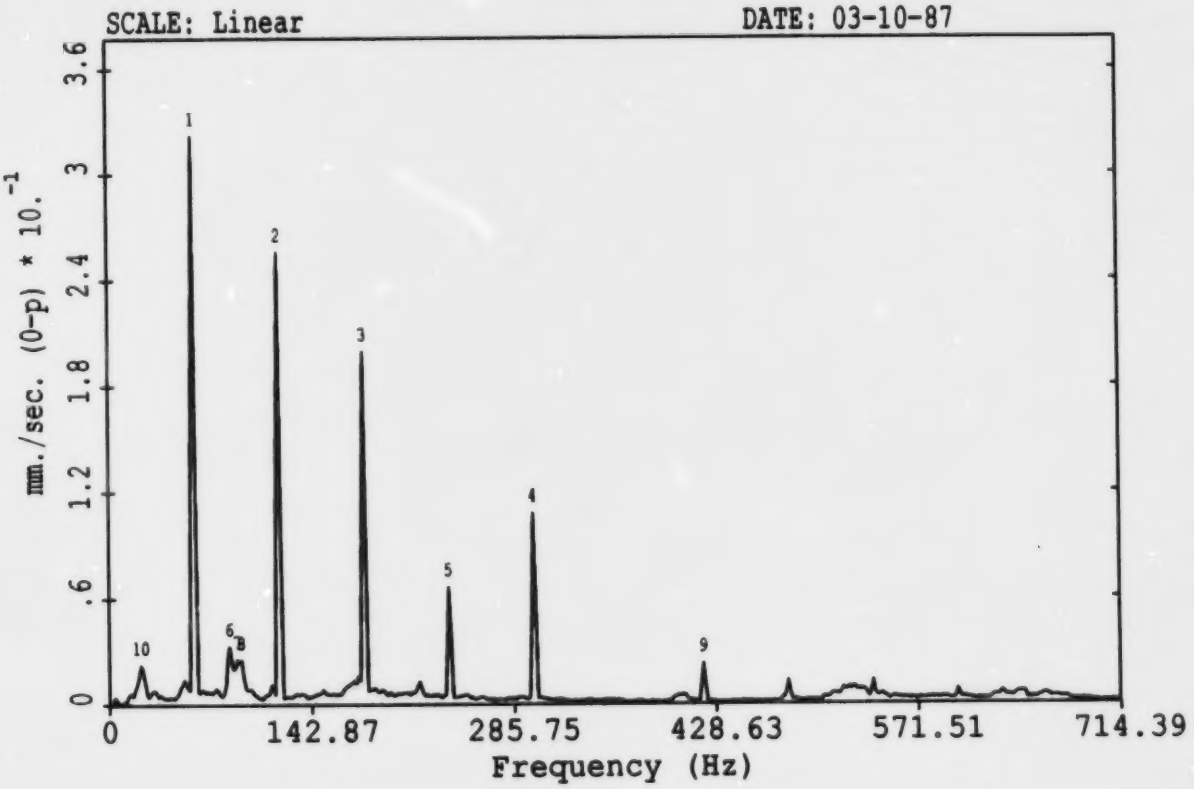


FIGURE 20

Darlington GS Standby Generator #4 AC Generator

SIGNAL : Outboard Brg. Casing Velocity Axial
SPEED : 3600 r.p.m.
PROCESS CONDITION : Load 13 MW

PEAK NO.	FREQUENCY	ORDER	AMPLITUDE
1	60.0	1.00	0.45
2	85.1	1.42	0.24
3	120.0	2.00	0.15
4	89.3	1.49	0.13
5	300.0	5.00	0.10
6	360.0	6.00	0.04
7	101.9	1.70	0.03
8	67.0	1.12	0.02
9	43.3	0.72	0.02
10	420.0	7.00	0.02

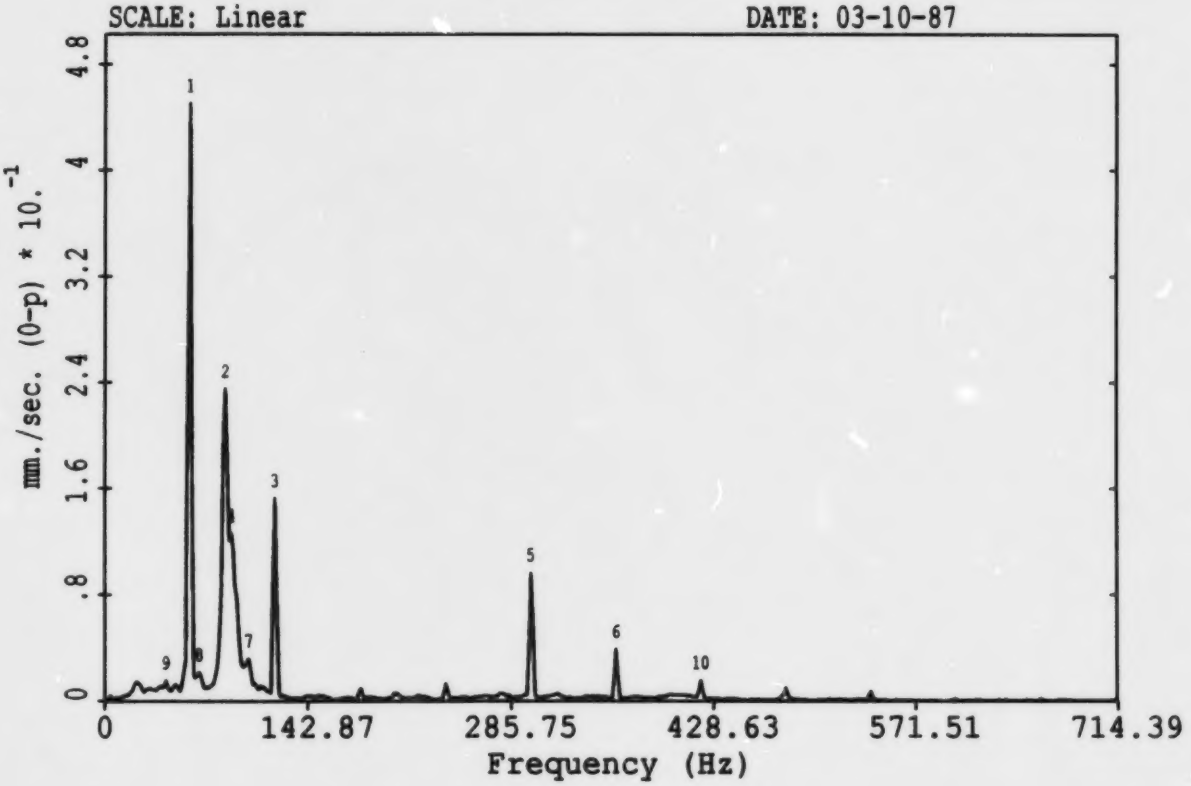


FIGURE 21

Darlington GS Standby Generator #4 AC Generator

SIGNAL : Inboard Brg. Casing Velocity X-Axis
SPEED : 3600 r.p.m.
PROCESS CONDITION : Load 13 MW

PEAK NO.	FREQUENCY	ORDER	AMPLITUDE
1	120.0	2.00	0.42
2	60.0	1.00	0.32
3	360.0	6.00	0.07
4	240.0	4.00	0.07
5	180.0	3.00	0.04
6	171.6	2.86	0.03
7	300.0	5.00	0.03
8	480.0	8.00	0.03
9	175.8	2.93	0.03
10	113.0	1.88	0.02

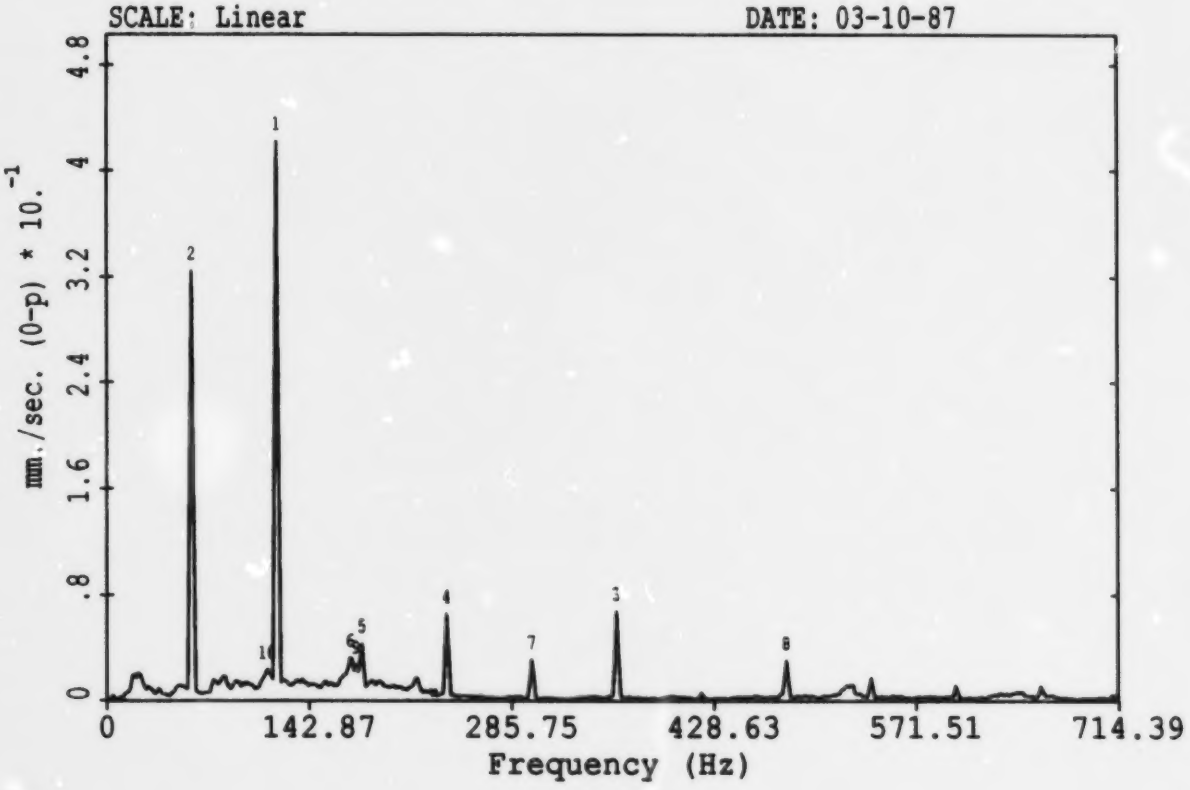


FIGURE 22

Darlington GS Standby Generator #4 AC Generator

SIGNAL : Inboard Brg. Casing Velocity Y-Axis
SPEED : 3600 r.p.m.
PROCESS CONDITION : Load 13 MW

PEAK NO.	FREQUENCY	ORDER	AMPLITUDE
1	60.0	1.00	0.44
2	240.0	4.00	0.18
3	120.0	2.00	0.11
4	360.0	6.00	0.07
5	180.0	3.00	0.07
6	300.0	5.00	0.07
7	173.0	2.88	0.04
8	219.1	3.65	0.04
9	175.8	2.93	0.04
10	22.3	0.37	0.03

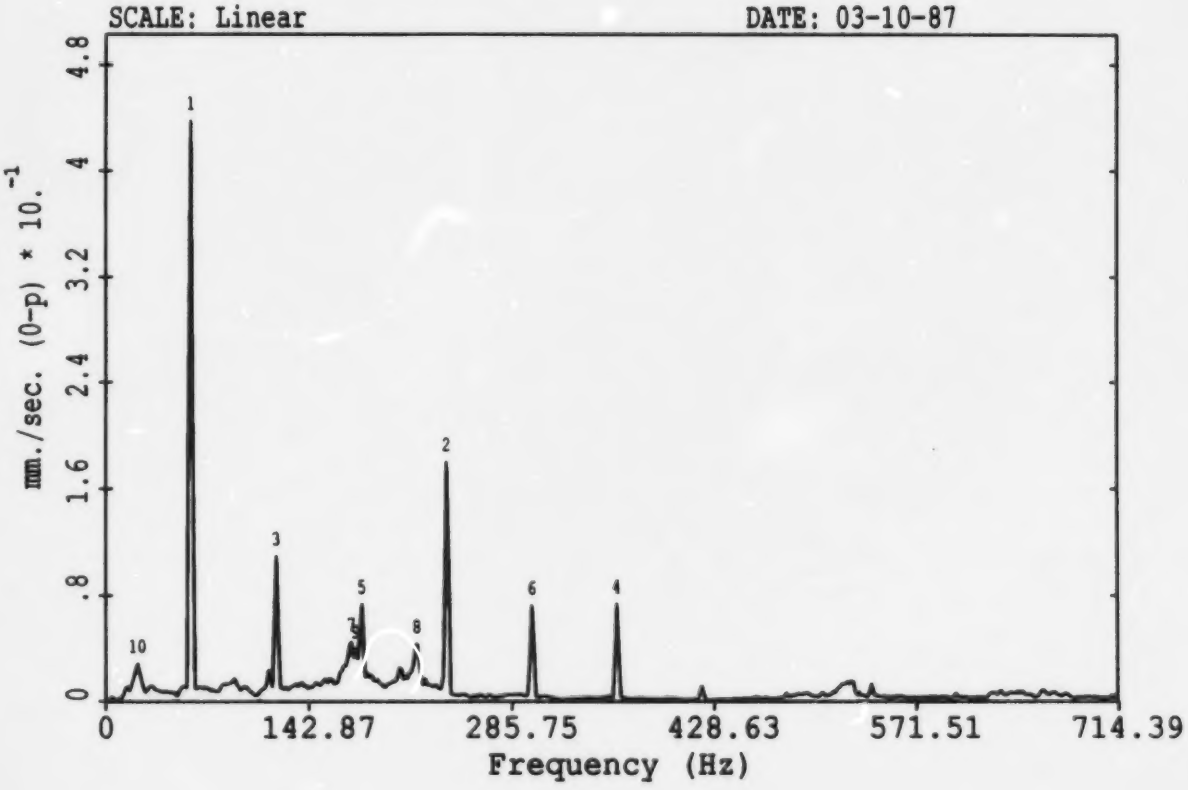


FIGURE 23

Darlington GS Standby Generator #4 AC Generator

SIGNAL : Inboard Brg. Casing Velocity Axial
SPEED : 3600 r.p.m.
PROCESS CONDITION : Load 13 MW

PEAK NO.	FREQUENCY	ORDER	AMPLITUDE
1	60.0	1.00	0.11
2	240.0	4.00	0.10
3	83.7	1.40	0.10
4	120.0	2.00	0.07
5	89.3	1.49	0.07
6	300.0	5.00	0.04
7	180.0	3.00	0.04
8	115.8	1.93	0.03
9	53.0	0.88	0.03
10	100.5	1.67	0.02

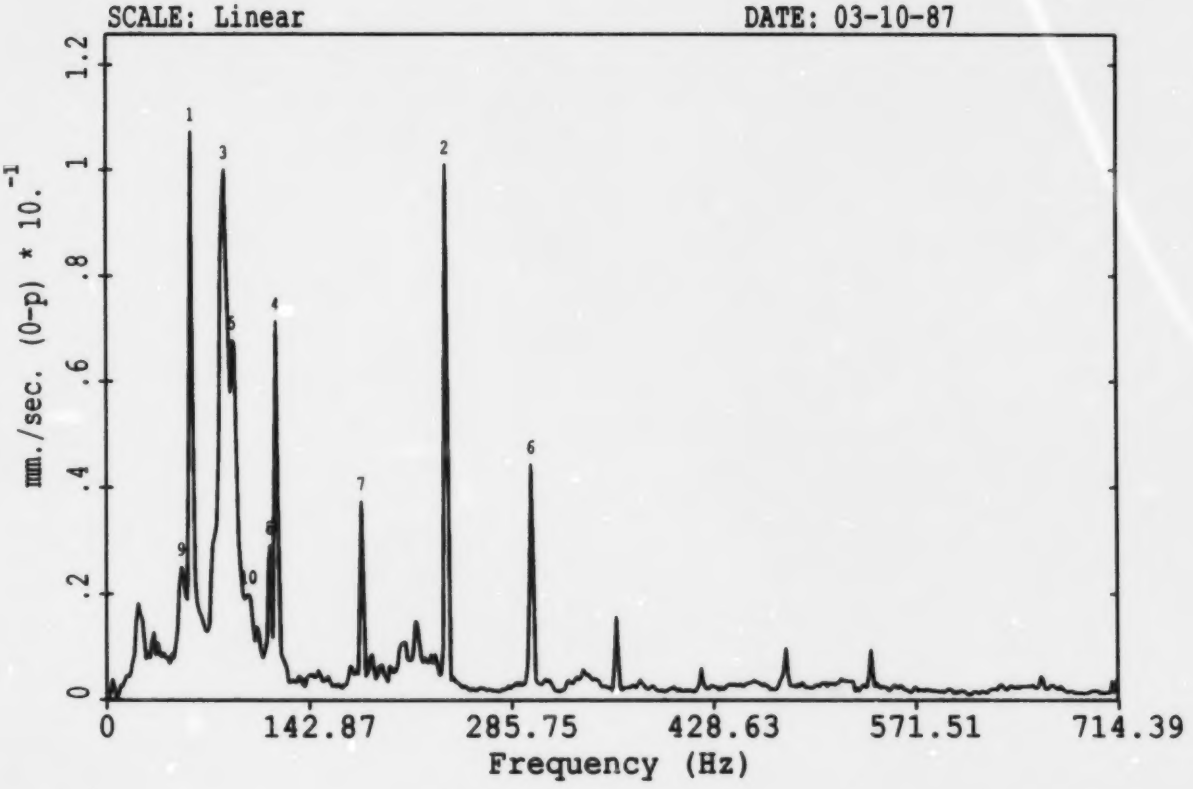


FIGURE 24

Darlington GS Standby Generator #4 AC Generator

SIGNAL : Outboard Brg. Casing Velocity X-Axis
SPEED : 3600 r.p.m.
PROCESS CONDITION : Load 20 MW

PEAK NO.	FREQUENCY	ORDER	AMPLITUDE
1	120.0	2.00	0.38
2	60.0	1.00	0.31
3	180.0	3.00	0.14
4	240.0	4.00	0.11
5	540.0	9.00	0.03
6	85.1	1.42	0.03
7	300.0	5.00	0.02
8	90.7	1.51	0.02
9	480.0	8.00	0.02
10	217.7	3.63	0.02

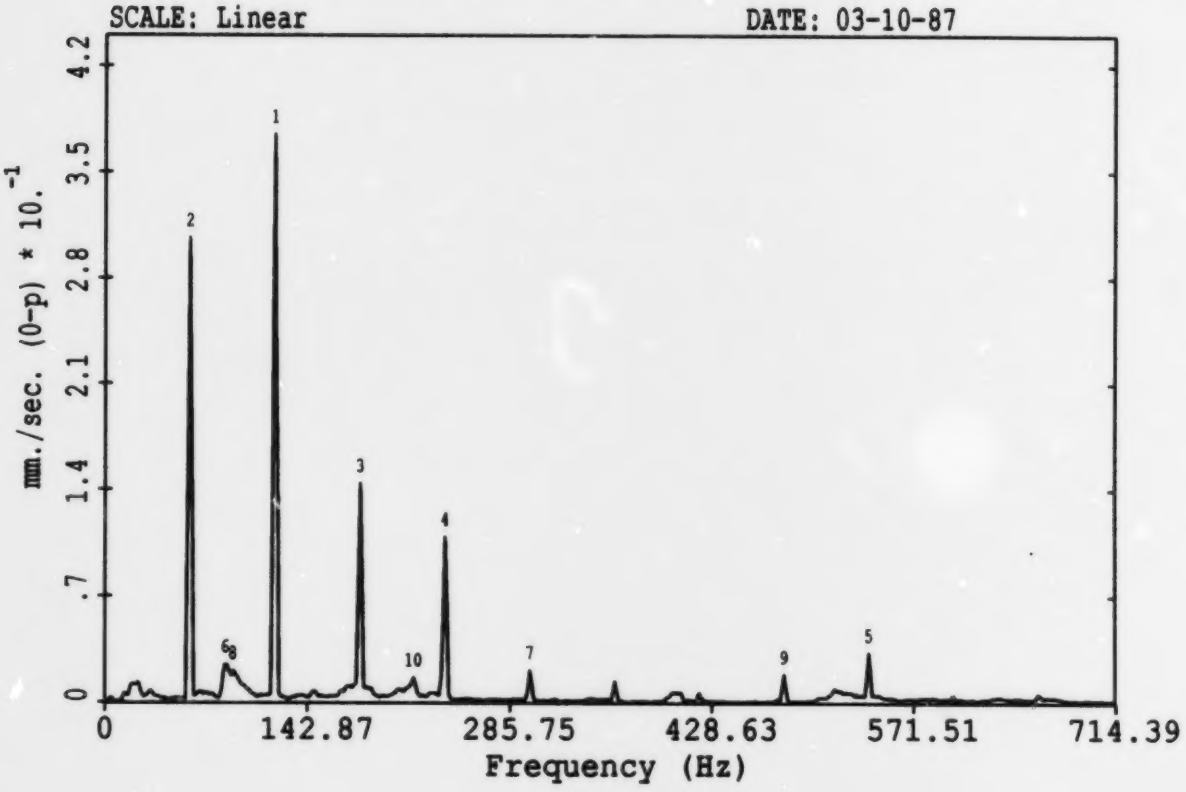


FIGURE 25

Darlington GS Standby Generator #4 AC Generator

SIGNAL : Outboard Brg. Casing Velocity Y-Axis
SPEED : 3600 r.p.m.
PROCESS CONDITION : Load 20 MW

PEAK NO.	FREQUENCY	ORDER	AMPLITUDE
1	120.0	2.00	0.33
2	60.0	1.00	0.29
3	180.0	3.00	0.19
4	240.0	4.00	0.19
5	300.0	5.00	0.12
6	85.1	1.42	0.04
7	90.7	1.51	0.03
8	420.0	7.00	0.02
9	22.3	0.37	0.02
10	217.7	3.63	0.02

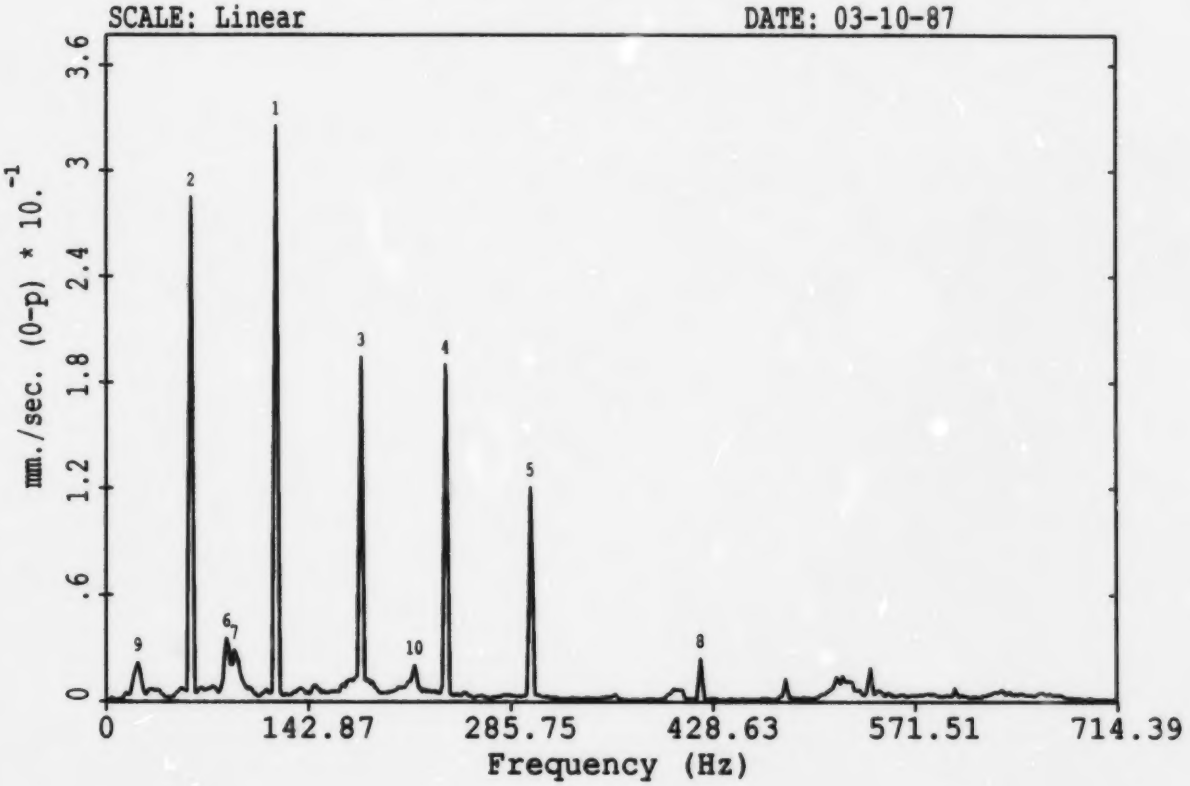


FIGURE 26

Darlington GS Standby Generator #4 AC Generator

SIGNAL : Outboard Brg. Casing Velocity Axial
SPEED : 3600 r.p.m.
PROCESS CONDITION : Load 20 MW

PEAK NO.	FREQUENCY	ORDER	AMPLITUDE
1	60.0	1.00	0.52
2	85.1	1.42	0.26
3	120.0	2.00	0.15
4	90.7	1.51	0.12
5	300.0	5.00	0.09
6	360.0	6.00	0.03
7	100.5	1.67	0.03
8	240.0	4.00	0.03
9	68.4	1.14	0.02
10	22.3	0.37	0.02

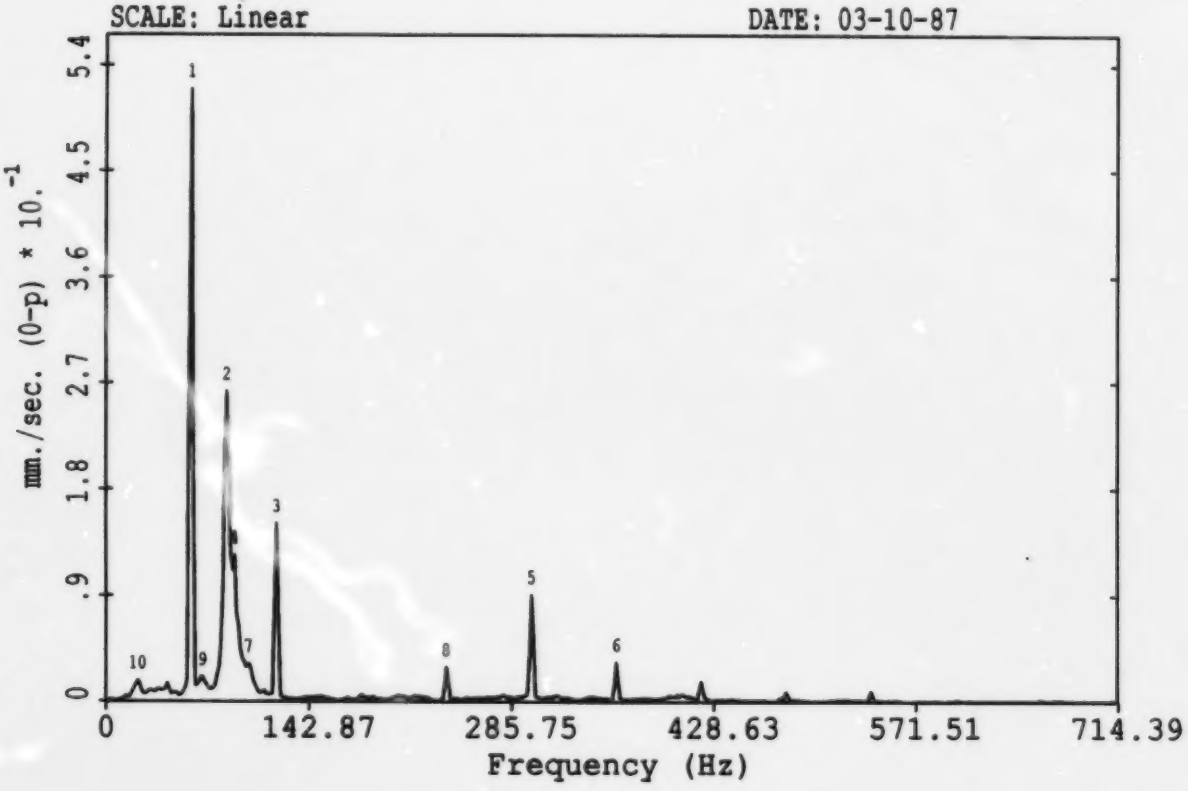


FIGURE 27

Darlington GS Standby Generator #4 AC Generator

SIGNAL : Inboard Brg. Casing Velocity X-Axis
SPEED : 3600 r.p.m.
PROCESS CONDITION : Load 20 MW

PEAK NO.	FREQUENCY	ORDER	AMPLITUDE
1	60.0	1.00	0.37
2	120.0	2.00	0.31
3	240.0	4.00	0.13
4	360.0	6.00	0.06
5	180.0	3.00	0.04
6	173.0	2.88	0.03
7	300.0	5.00	0.03
8	480.0	8.00	0.03
9	22.3	0.37	0.03
10	217.7	3.63	0.03

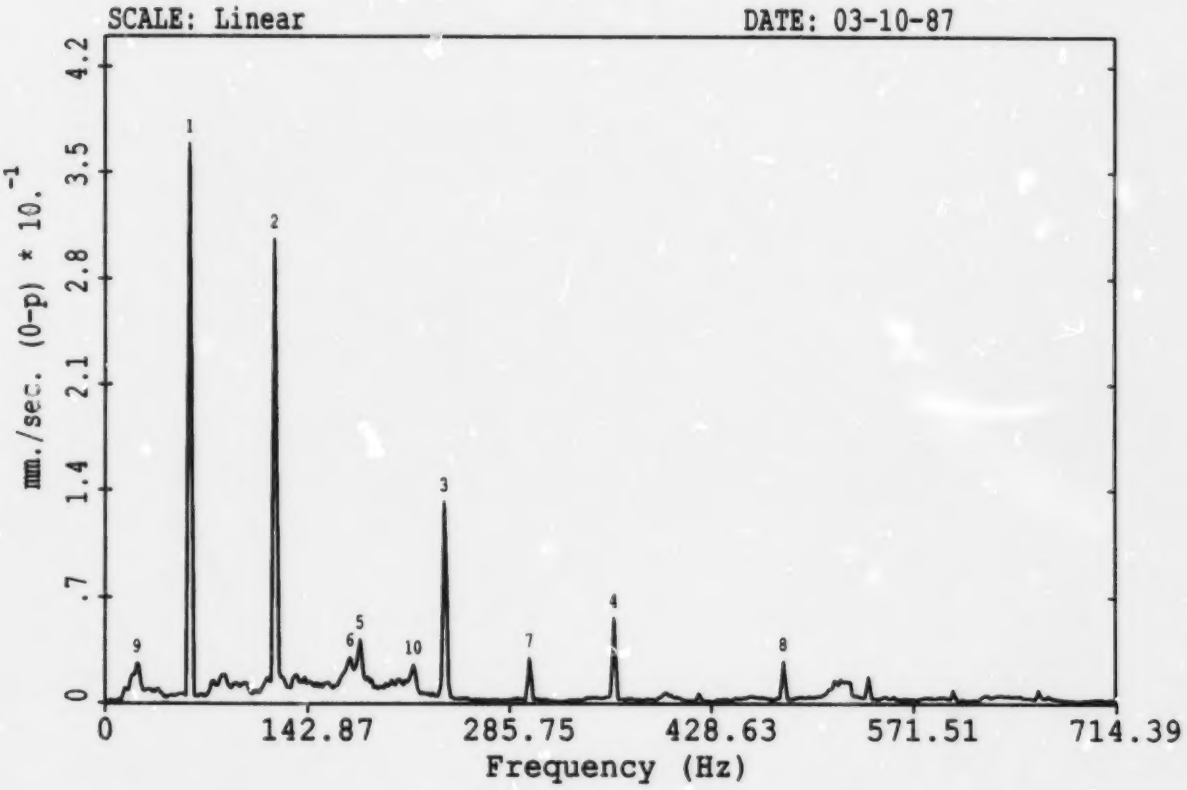


FIGURE 28

Darlington GS Standby Generator #4 AC Generator

SIGNAL : Inboard Brg. Casing Velocity Y-Axis
SPEED : 3600 r.p.m.
PROCESS CONDITION : Load 20 MW

PEAK NO.	FREQUENCY	ORDER	AMPLITUDE
1	60.0	1.00	0.48
2	240.0	4.00	0.30
3	120.0	2.00	0.23
4	300.0	5.00	0.07
5	217.7	3.63	0.06
6	360.0	6.00	0.06
7	180.0	3.00	0.06
8	173.0	2.88	0.04
9	207.9	3.46	0.03
10	22.3	0.37	0.03

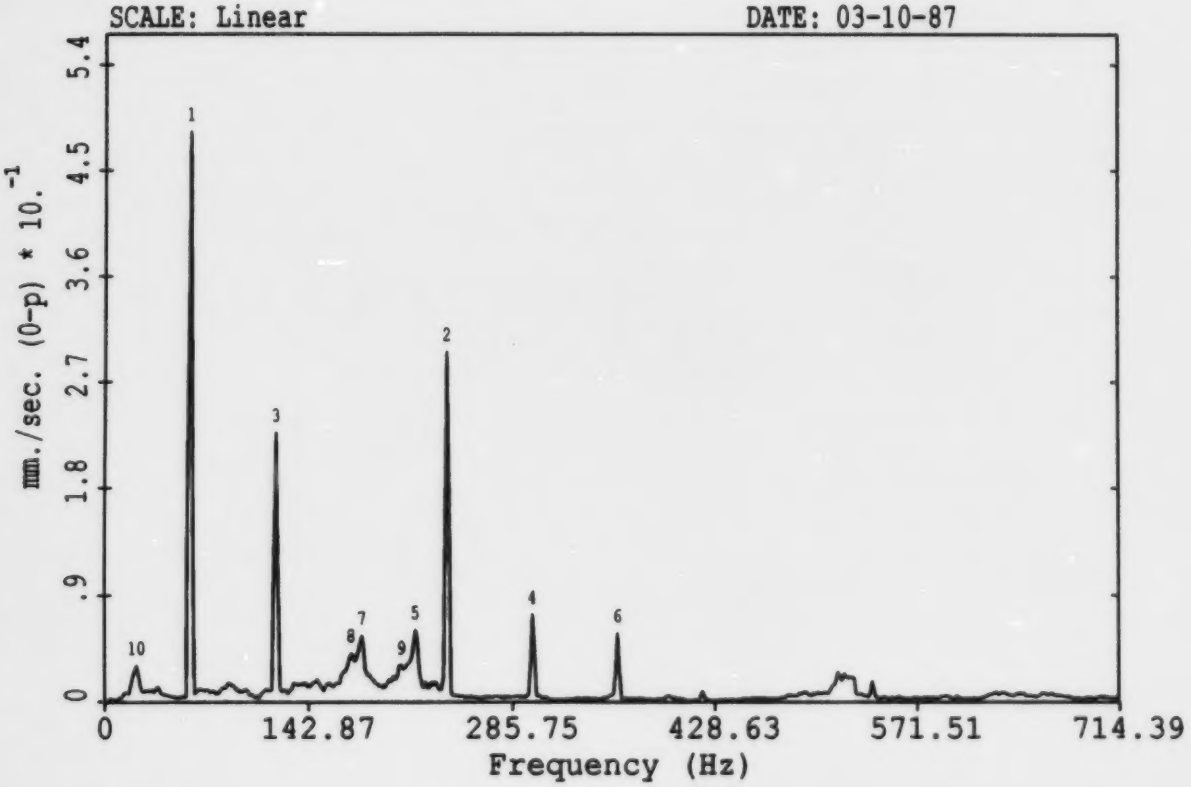


FIGURE 29

Darlington GS Standby Generator #4 AC Generator

SIGNAL : Inboard Brg. Casing Velocity Axial
SPEED : 3600 r.p.m.
PROCESS CONDITION : Load 20 MW

PEAK NO.	FREQUENCY	ORDER	AMPLITUDE
1	240.0	4.00	0.21
2	60.0	1.00	0.14
3	83.7	1.40	0.10
4	300.0	5.00	0.04
5	76.7	1.28	0.04
6	120.0	2.00	0.03
7	100.5	1.67	0.02
8	96.3	1.60	0.02
9	22.3	0.37	0.02
10	217.7	3.63	0.02

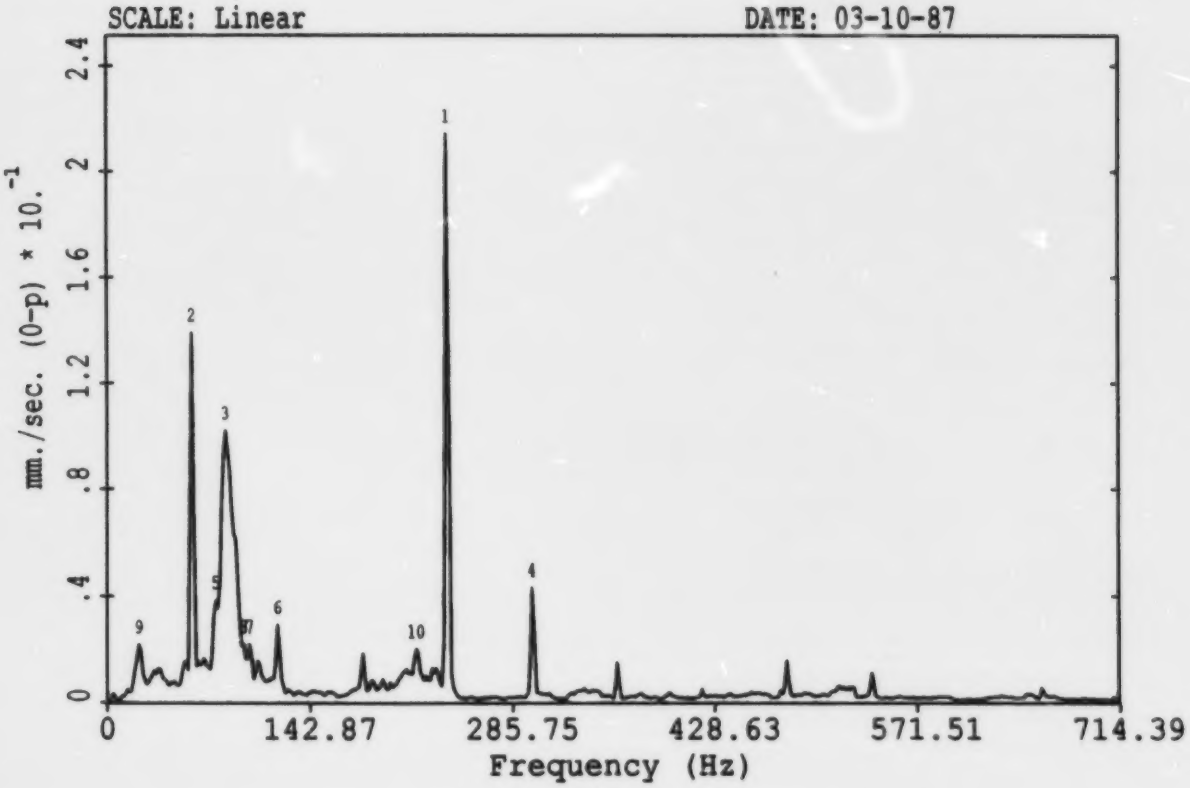


FIGURE 30

Darlington GS Standby Generator #4 AC Generator

SIGNAL : Outboard Brg. Casing Velocity X-Axis
SPEED : 3600 r.p.m.
PROCESS CONDITION : Load 26 MW

PEAK NO.	FREQUENCY	ORDER	AMPLITUDE
1	120.0	2.00	0.36
2	60.0	1.00	0.30
3	240.0	4.00	0.14
4	180.0	3.00	0.12
5	540.0	9.00	0.04
6	92.1	1.53	0.03
7	86.5	1.44	0.02
8	480.0	8.00	0.02
9	300.0	5.00	0.02
10	209.3	3.49	0.02

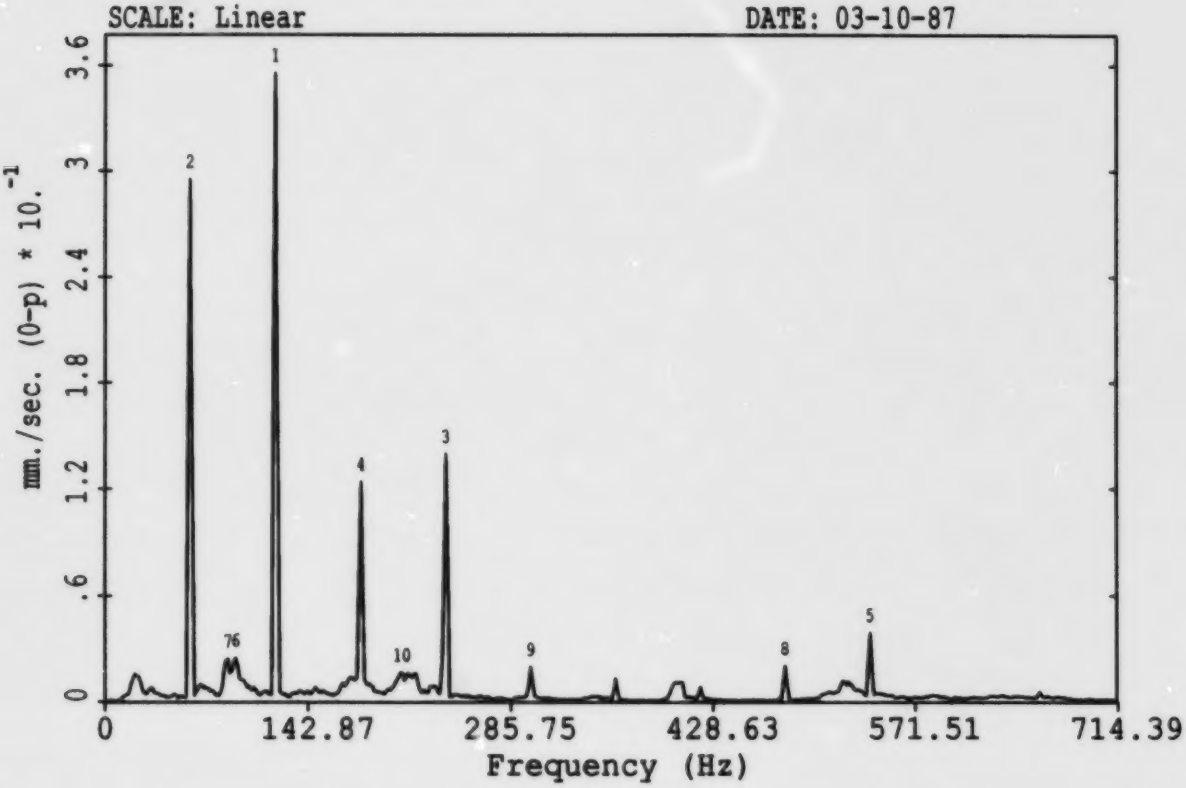


FIGURE 31

Darlington GS Standby Generator #4 AC Generator

SIGNAL : Outboard Brg. Casing Velocity Y-Axis
SPEED : 3600 r.p.m.
PROCESS CONDITION : Load 26 MW

PEAK NO.	FREQUENCY	ORDER	AMPLITUDE
1	120.0	2.00	0.32
2	60.0	1.00	0.26
3	240.0	4.00	0.24
4	180.0	3.00	0.17
5	300.0	5.00	0.14
6	22.3	0.37	0.03
7	85.1	1.42	0.03
8	540.0	9.00	0.03
9	92.1	1.53	0.02
10	420.0	7.00	0.02

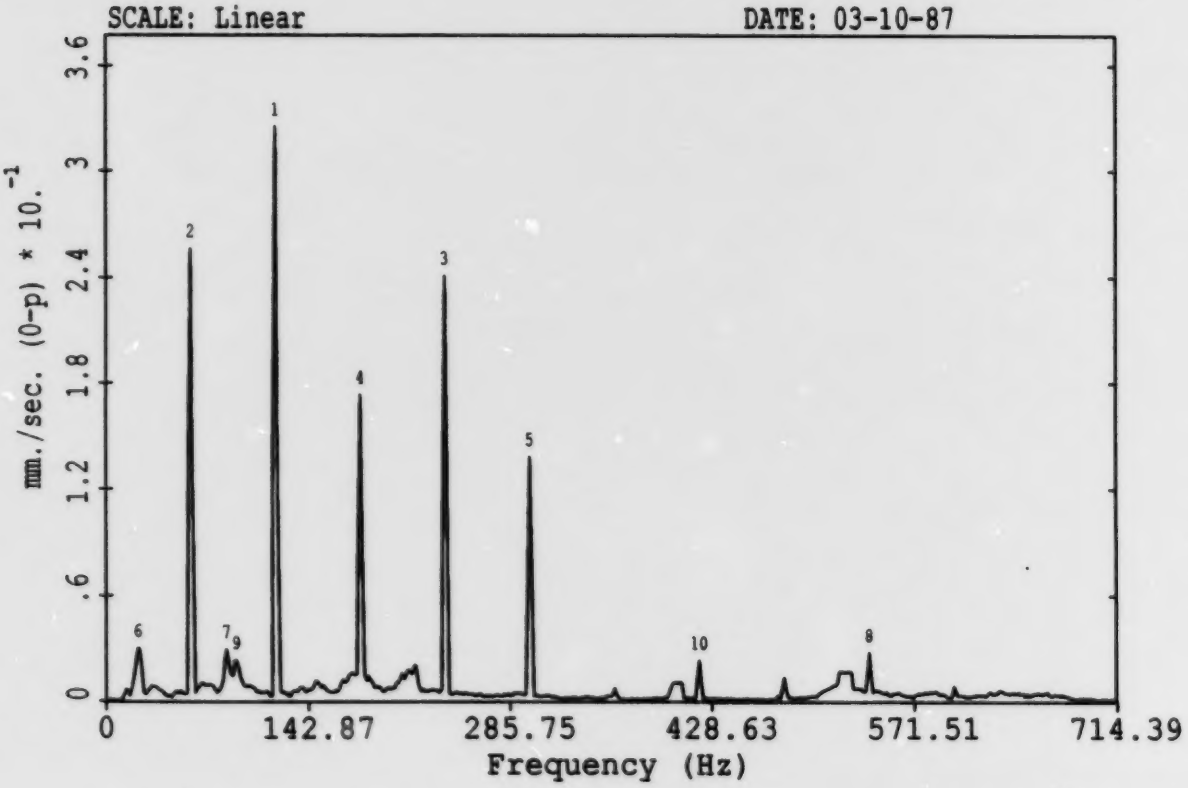


FIGURE 32

Darlington GS Standby Generator #4 AC Generator

SIGNAL : Outboard Brg. Casing Velocity Axial
SPEED : 3600 r.p.m.
PROCESS CONDITION : Load 26 MW

PEAK NO.	FREQUENCY	ORDER	AMPLITUDE
1	60.0	1.00	0.53
2	85.1	1.42	0.22
3	120.0	2.00	0.14
4	90.7	1.51	0.10
5	300.0	5.00	0.07
6	240.0	4.00	0.04
7	360.0	6.00	0.03
8	67.0	1.12	0.03
9	101.9	1.70	0.03
10	104.6	1.74	0.03

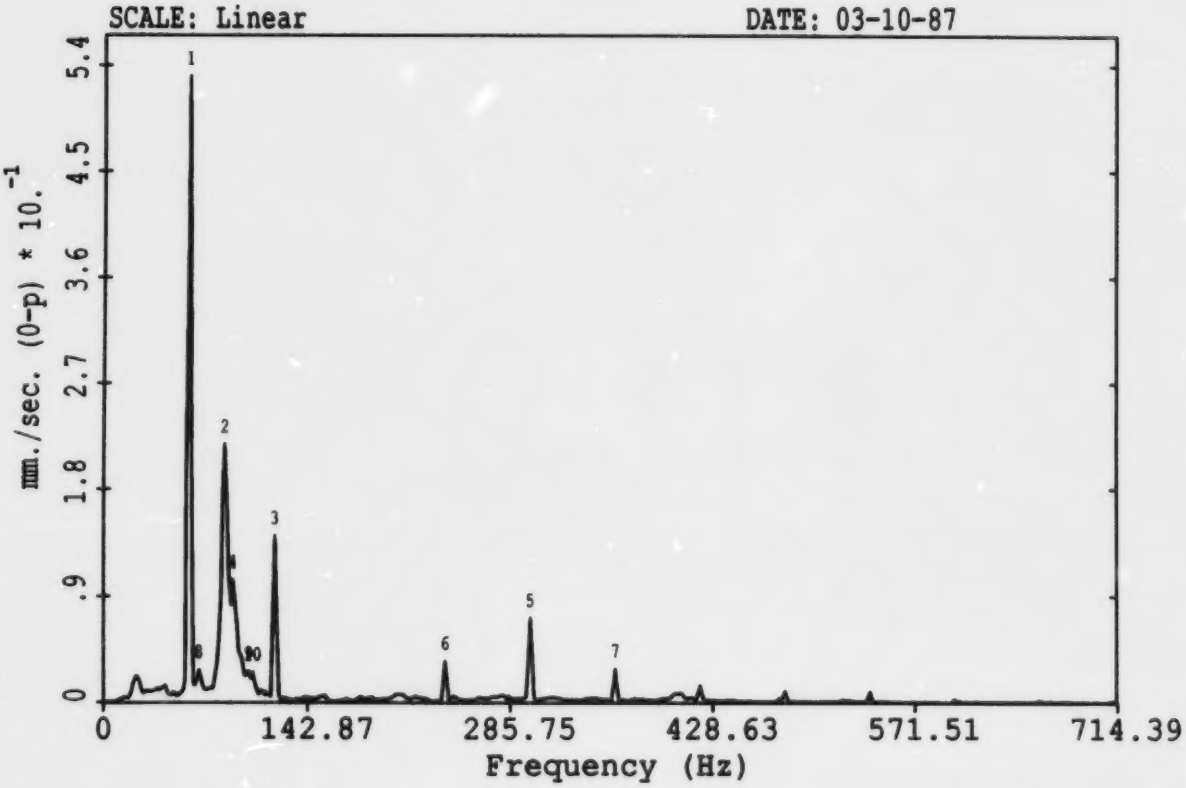


FIGURE 33

Darlington GS Standby Generator #4 AC Generator

SIGNAL : Inboard Brg. Casing Velocity X-Axis
SPEED : 3600 r.p.m.
PROCESS CONDITION : Load 26 MW

PEAK NO.	FREQUENCY	ORDER	AMPLITUDE
1	60.0	1.00	0.36
2	120.0	2.00	0.28
3	240.0	4.00	0.15
4	180.0	3.00	0.07
5	360.0	6.00	0.06
6	173.0	2.88	0.04
7	300.0	5.00	0.04
8	219.1	3.65	0.03
9	23.7	0.40	0.03
10	167.4	2.79	0.03

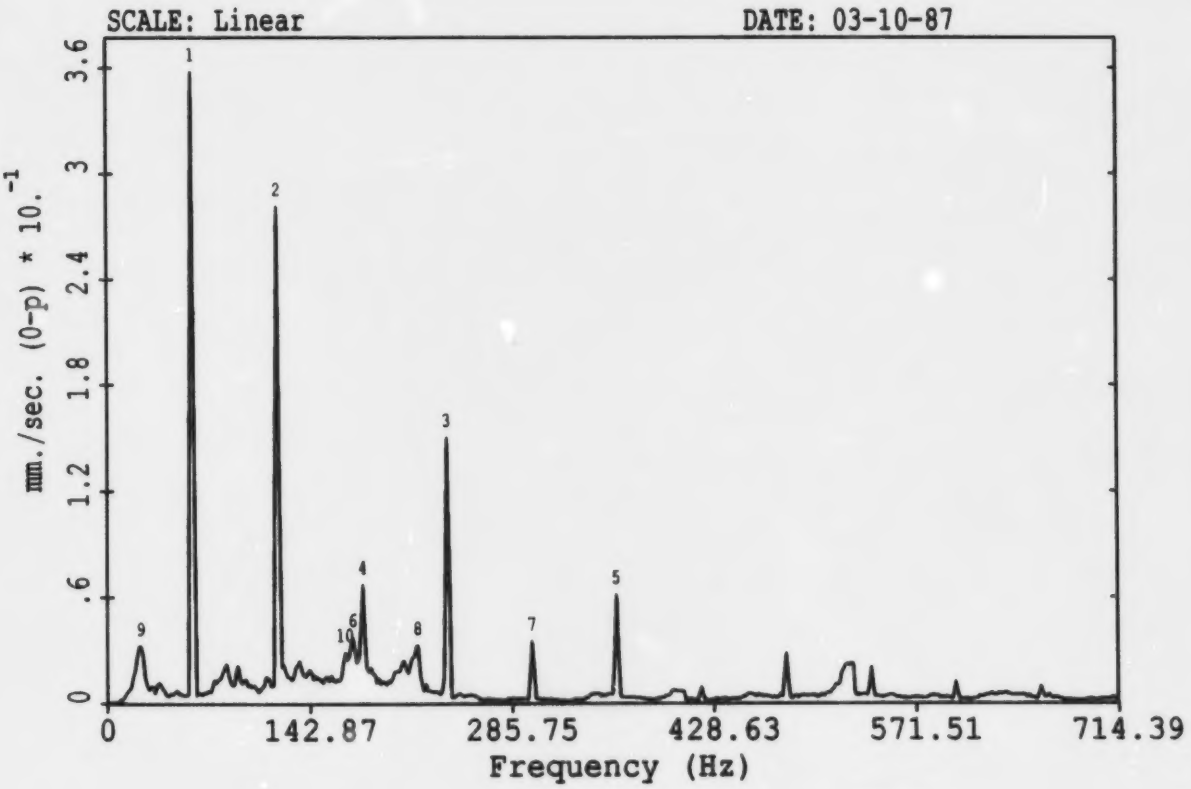


FIGURE 34

Darlington GS Standby Generator #4 AC Generator

SIGNAL : Inboard Brg. Casing Velocity Y-Axis
SPEED : 3600 r.p.m.
PROCESS CONDITION : Load 26 MW

PEAK NO.	FREQUENCY	ORDER	AMPLITUDE
1	60.0	1.00	0.47
2	240.0	4.00	0.34
3	120.0	2.00	0.21
4	219.1	3.65	0.08
5	300.0	5.00	0.07
6	180.0	3.00	0.06
7	360.0	6.00	0.06
8	209.3	3.49	0.05
9	173.0	2.88	0.05
10	22.3	0.37	0.04

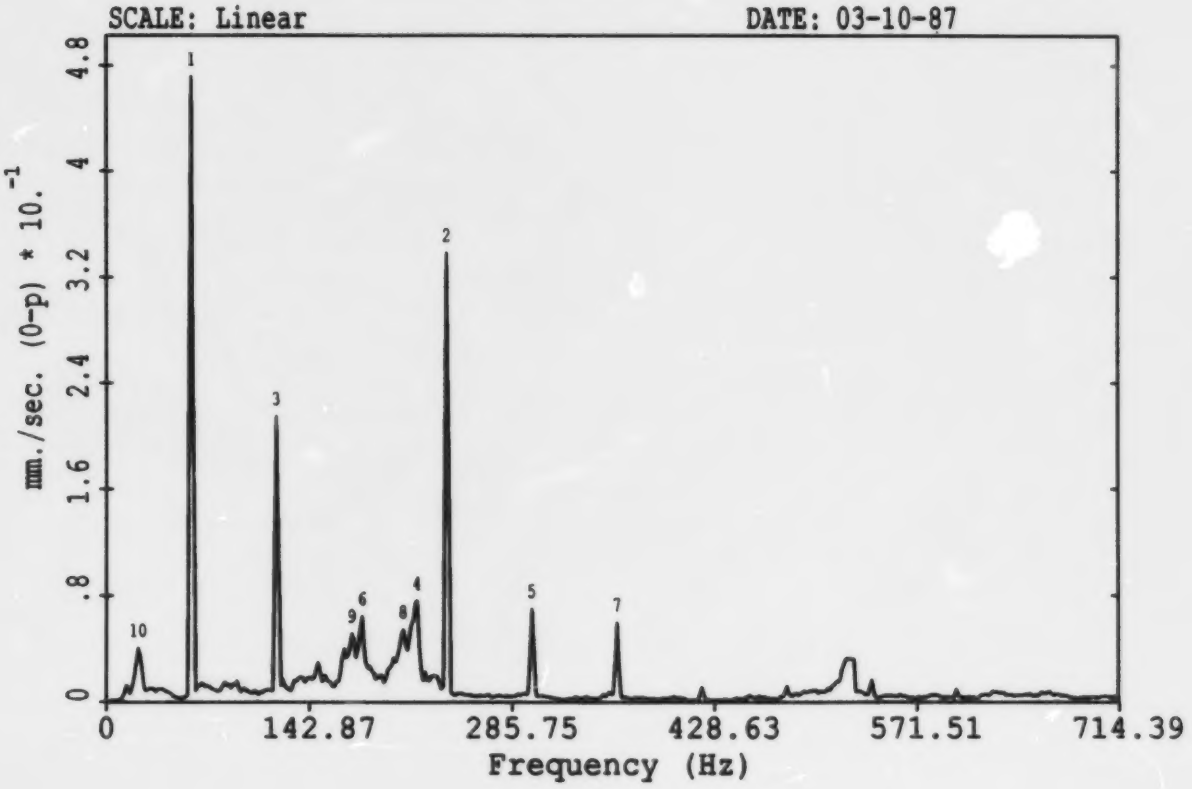


FIGURE 35

Darlington GS Standby Generator #4 AC Generator

SIGNAL : Inboard Brg. Casing Velocity Axial
SPEED : 3600 r.p.m.
PROCESS CONDITION : Load 26 MW

PEAK NO.	FREQUENCY	ORDER	AMPLITUDE
1	240.0	4.00	0.24
2	83.7	1.40	0.13
3	60.0	1.00	0.12
4	300.0	5.00	0.06
5	89.3	1.49	0.06
6	120.0	2.00	0.03
7	22.3	0.37	0.03
8	219.1	3.65	0.03
9	209.3	3.49	0.03
10	96.3	1.60	0.02

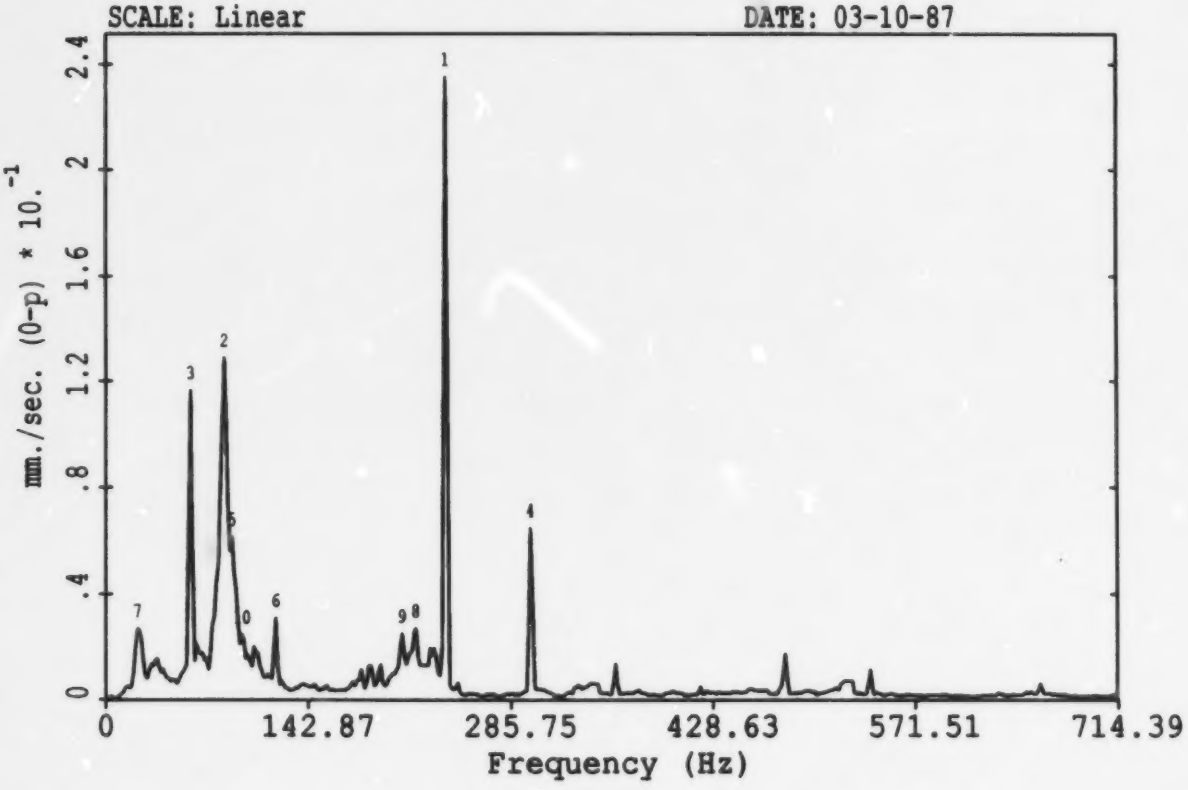


FIGURE 36

Darlington GS Standby Generator #4 Power Turbine

SIGNAL : Inboard Brg. Casing Velocity X-Axis
SPEED : 3600 r.p.m.
PROCESS CONDITION : Load 0 MW

PEAK NO.	FREQUENCY	ORDER	AMPLITUDE
1	60.0	1.00	1.75
2	18.1	0.30	0.63
3	48.8	0.81	0.22
4	238.6	3.98	0.21
5	53.0	0.88	0.19
6	25.1	0.42	0.19
7	44.6	0.74	0.18
8	65.6	1.09	0.17
9	27.9	0.47	0.17
10	32.1	0.53	0.15

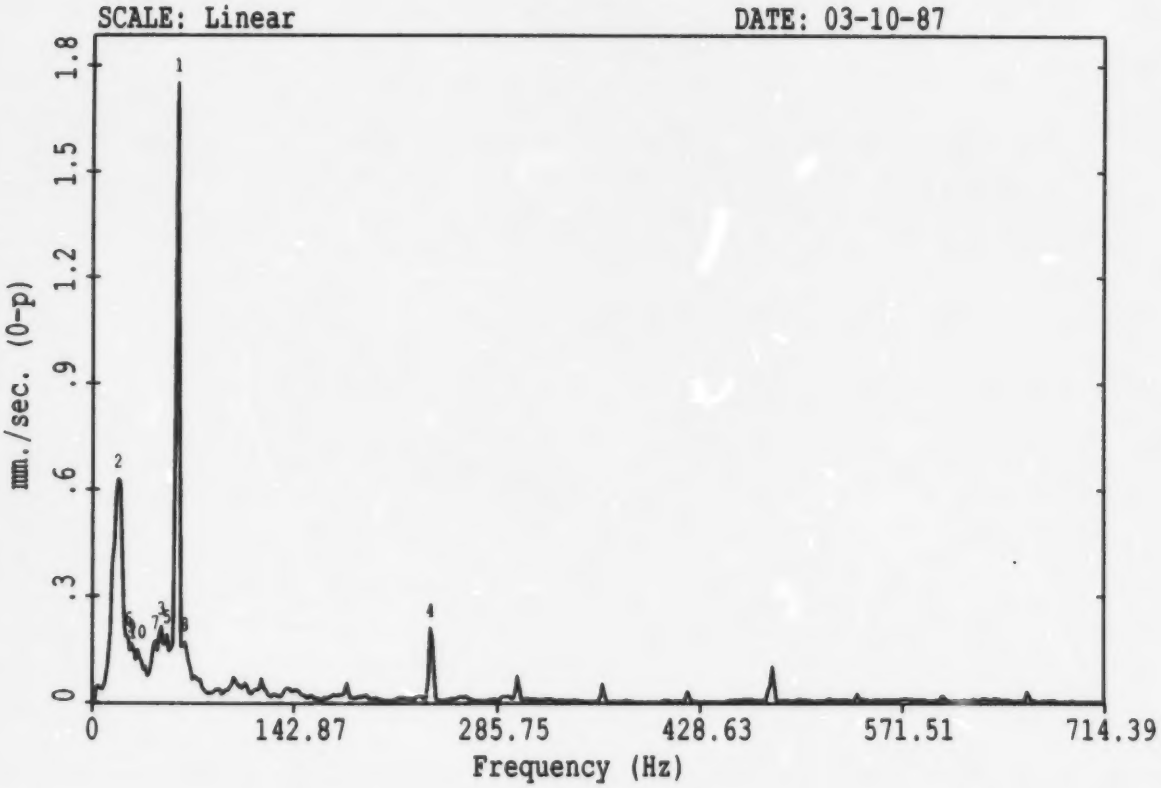


FIGURE 37

Darlington GS Standby Generator #4 Power Turbine

SIGNAL : Inboard Brg. Casing Velocity Y-Axis
SPEED : 3600 r.p.m.
PROCESS CONDITION : Load 0 MW

PEAK NO.	FREQUENCY	ORDER	AMPLITUDE
1	60.0	1.00	1.91
2	15.3	0.26	0.38
3	19.5	0.33	0.29
4	55.8	0.93	0.27
5	238.6	3.98	0.26
6	48.8	0.81	0.22
7	32.1	0.53	0.20
8	120.0	2.00	0.18
9	37.7	0.63	0.18
10	65.6	1.09	0.18

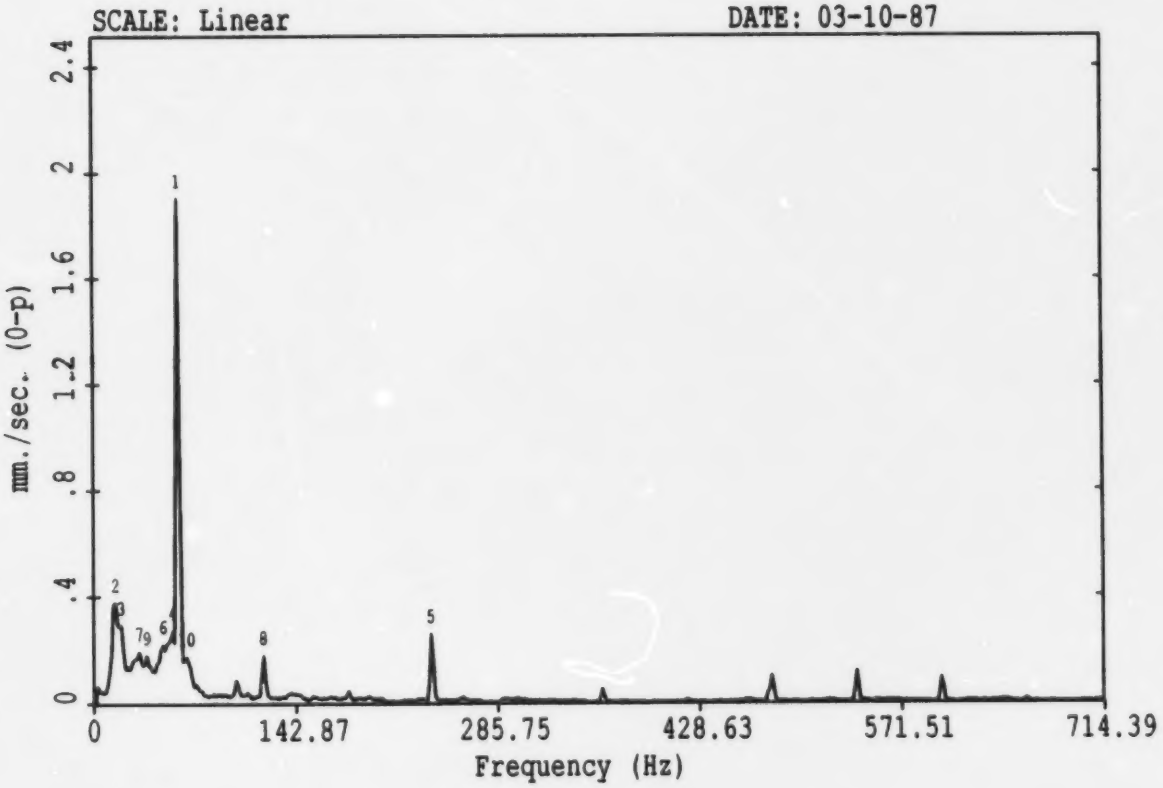


FIGURE 38

Darlington GS Standby Generator #4 Power Turbine

SIGNAL : Inboard Brg. Casing Velocity Axial
SPEED : 3600 r.p.m.
PROCESS CONDITION : Load 0 MW

PEAK NO.	FREQUENCY	ORDER	AMPLITUDE
1	15.3	0.26	0.81
2	60.0	1.00	0.63
3	40.5	0.67	0.49
4	36.3	0.60	0.47
5	238.6	3.98	0.32
6	32.1	0.53	0.27
7	25.1	0.42	0.24
8	540.0	9.00	0.23
9	480.0	8.00	0.15
10	360.0	6.00	0.13

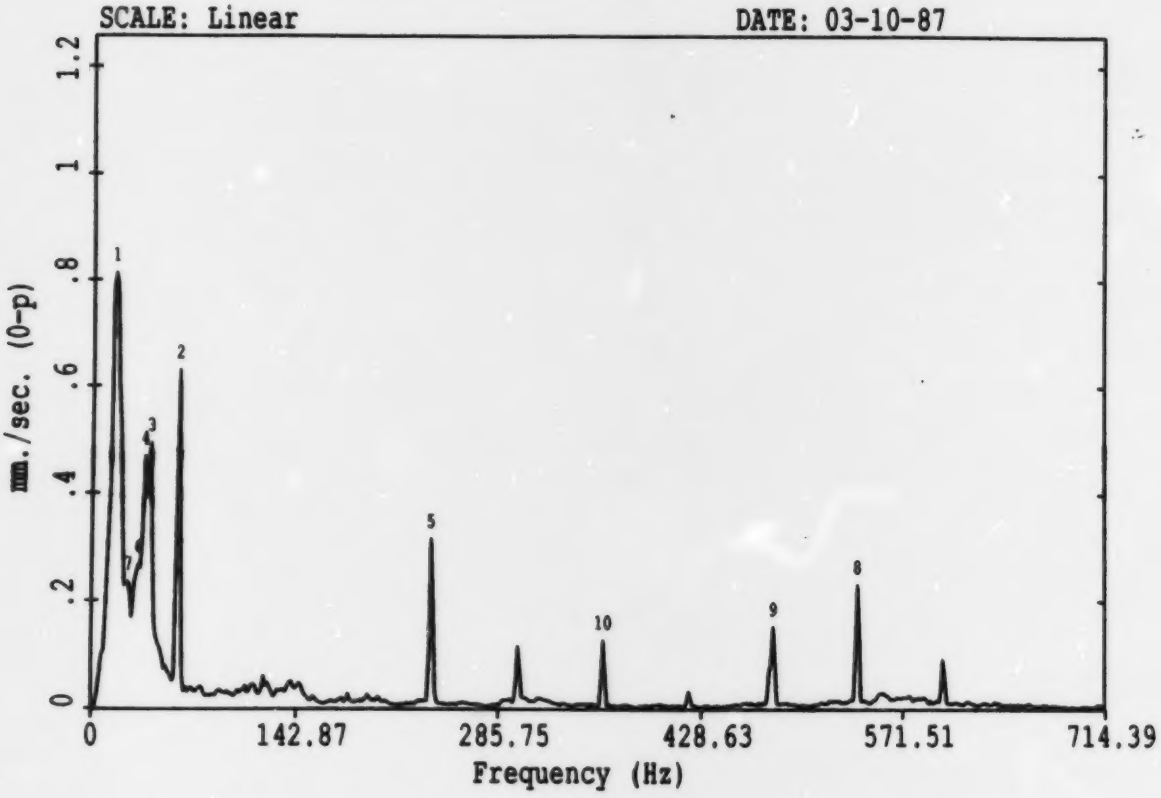


FIGURE 39

Darlington GS Standby Generator #4 Power Turbine

SIGNAL : Outboard Brg. Casing Velocity Horiz.
SPEED : 3600 r.p.m.
PROCESS CONDITION : Load 0 MW

PEAK NO.	FREQUENCY	ORDER	AMPLITUDE
1	60.0	1.00	2.31
2	19.5	0.33	1.25
3	238.6	3.98	0.71
4	120.0	2.00	0.47
5	32.1	0.53	0.35
6	47.4	0.79	0.22
7	300.0	5.00	0.22
8	37.7	0.63	0.20
9	540.0	9.00	0.19
10	41.9	0.70	0.17

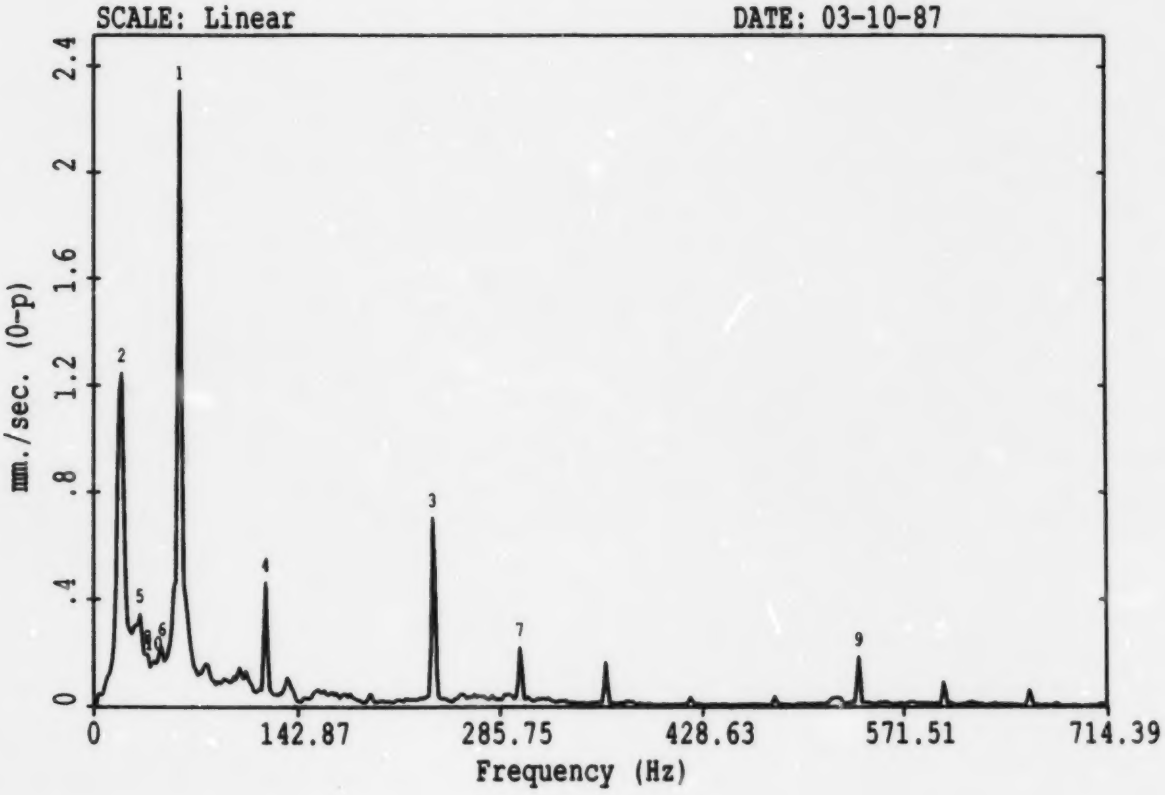


FIGURE 40
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Darlington GS Standby Generator #4 Power Turbine

SIGNAL : Outboard Brg. Casing Velocity Vert.
SPEED : 3600 r.p.m.
PROCESS CONDITION : Load 0 MW

PEAK NO.	FREQUENCY	ORDER	AMPLITUDE
1	60.0	1.00	3.91
2	15.3	0.26	1.80
3	238.6	3.98	0.83
4	120.0	2.00	0.68
5	37.7	0.63	0.39
6	180.0	3.00	0.38
7	25.1	0.42	0.31
8	48.8	0.81	0.29
9	360.0	6.00	0.27
10	65.6	1.09	0.26

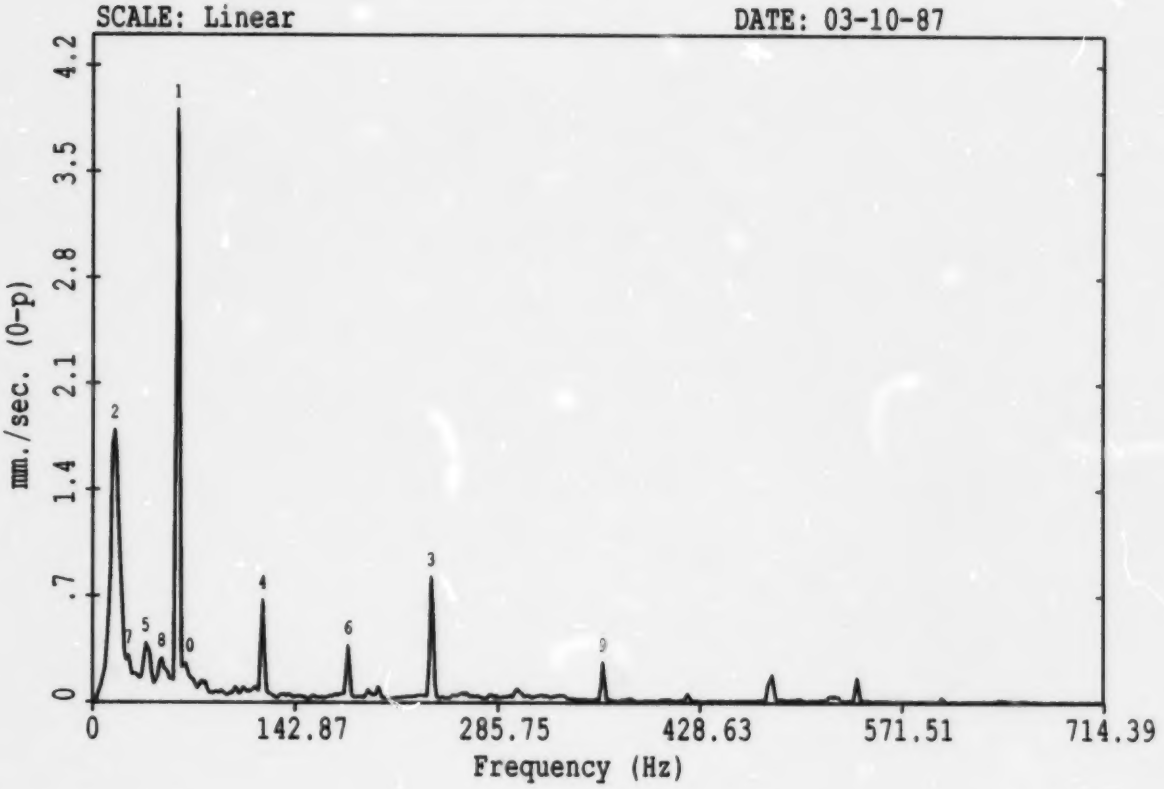

FIGURE 41

Darlington GS Standby Generator #4 Power Turbine

SIGNAL : Outboard Brg. Casing Velocity Axial
SPEED : 3600 r.p.m.
PROCESS CONDITION : Load 0 MW

PEAK NO.	FREQUENCY	ORDER	AMPLITUDE
1	15.3	0.26	0.84
2	60.0	1.00	0.70
3	40.5	0.67	0.44
4	36.3	0.60	0.42
5	32.1	0.53	0.27
6	25.1	0.42	0.25
7	540.0	9.00	0.19
8	480.0	8.00	0.16
9	47.4	0.79	0.13
10	180.0	3.00	0.13

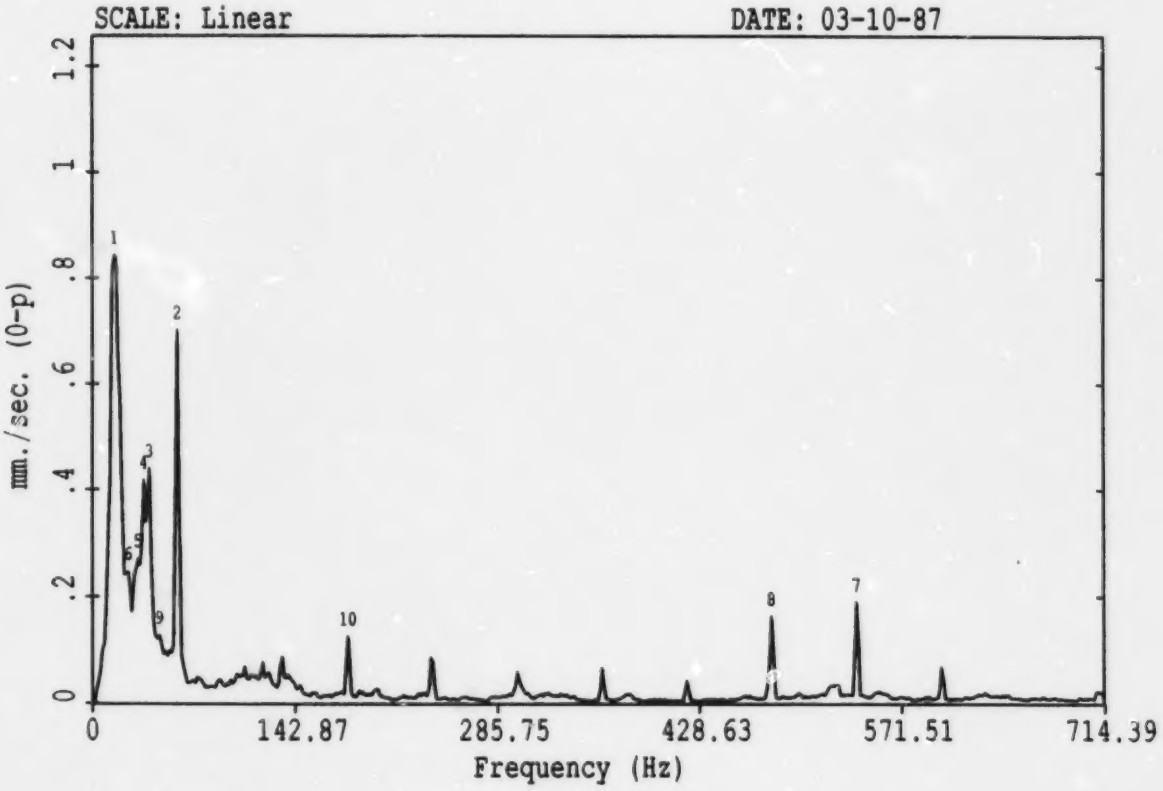

FIGURE 42

Darlington GS Standby Generator #4 Power Turbine

SIGNAL : Inboard Brg. Casing Velocity X-Axis
SPEED : 3600 r.p.m.
PROCESS CONDITION : Load 7 MW

PEAK NO.	FREQUENCY	ORDER	AMPLITUDE
1	60.0	1.00	1.01
2	18.1	0.30	0.89
3	26.5	0.44	0.22
4	238.6	3.98	0.19
5	110.2	1.84	0.18
6	53.0	0.88	0.17
7	65.6	1.09	0.14
8	48.8	0.81	0.14
9	40.5	0.67	0.10
10	36.3	0.60	0.10

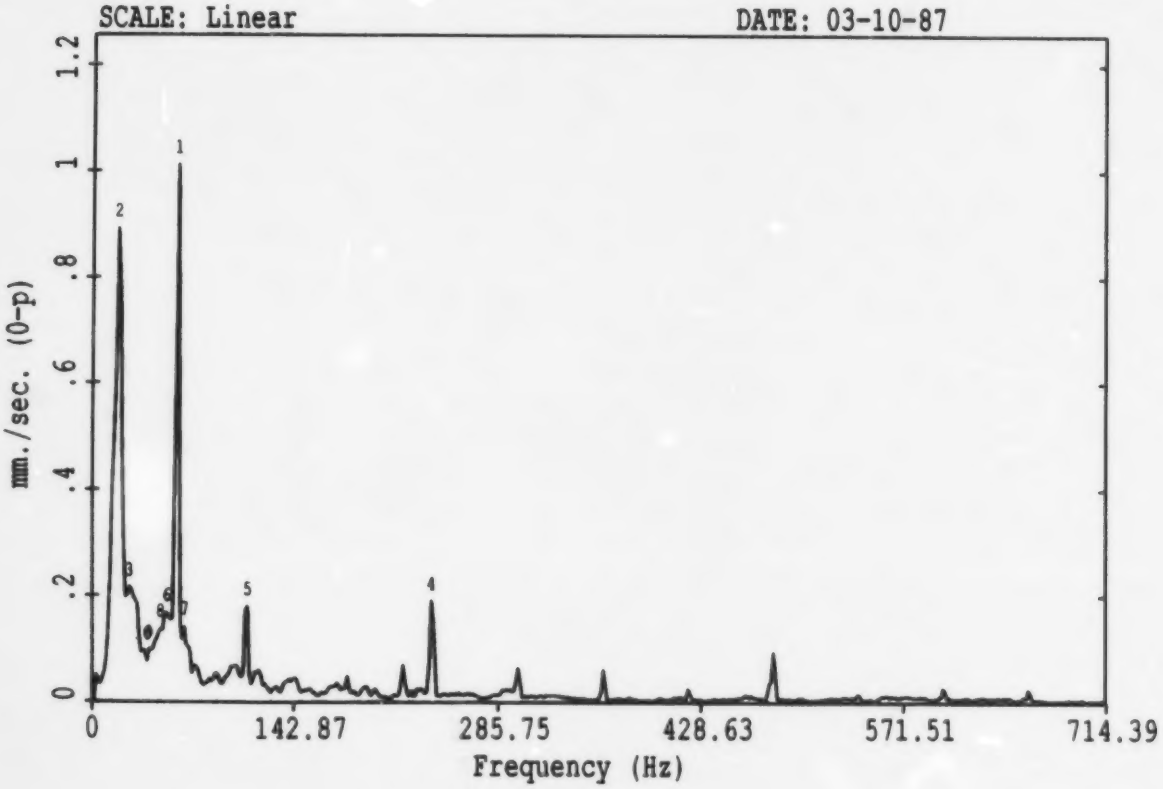

FIGURE 43

Darlington GS Standby Generator #4 Power Turbine

SIGNAL : Inboard Brg. Casing Velocity Y-Axis
SPEED : 3600 r.p.m.
PROCESS CONDITION : Load 7 MW

PEAK NO.	FREQUENCY	ORDER	AMPLITUDE
1	60.0	1.00	0.56
2	14.0	0.23	0.34
3	19.5	0.33	0.31
4	30.7	0.51	0.25
5	54.4	0.91	0.25
6	120.0	2.00	0.22
7	46.0	0.77	0.22
8	27.9	0.47	0.22
9	238.6	3.98	0.21
10	65.6	1.09	0.16

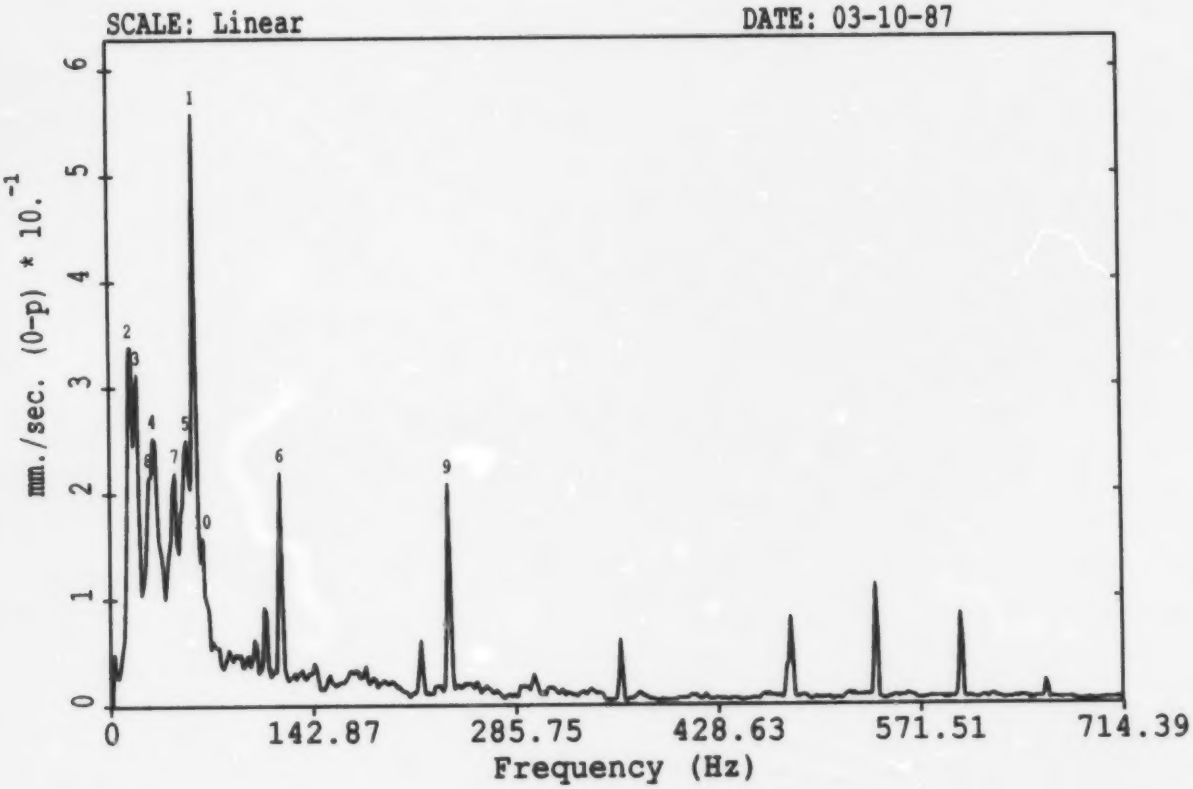

FIGURE 44

Darlington GS Standby Generator #4 Power Turbine

SIGNAL : Inboard Brg. Casing Velocity Axial
SPEED : 3600 r.p.m.
PROCESS CONDITION : Load 7 MW

PEAK NO.	FREQUENCY	ORDER	AMPLITUDE
1	15.3	0.26	0.84
2	60.0	1.00	0.75
3	36.3	0.60	0.41
4	40.5	0.67	0.37
5	32.1	0.53	0.33
6	238.6	3.98	0.27
7	26.5	0.44	0.25
8	540.0	9.00	0.22
9	360.0	6.00	0.14
10	480.0	8.00	0.13

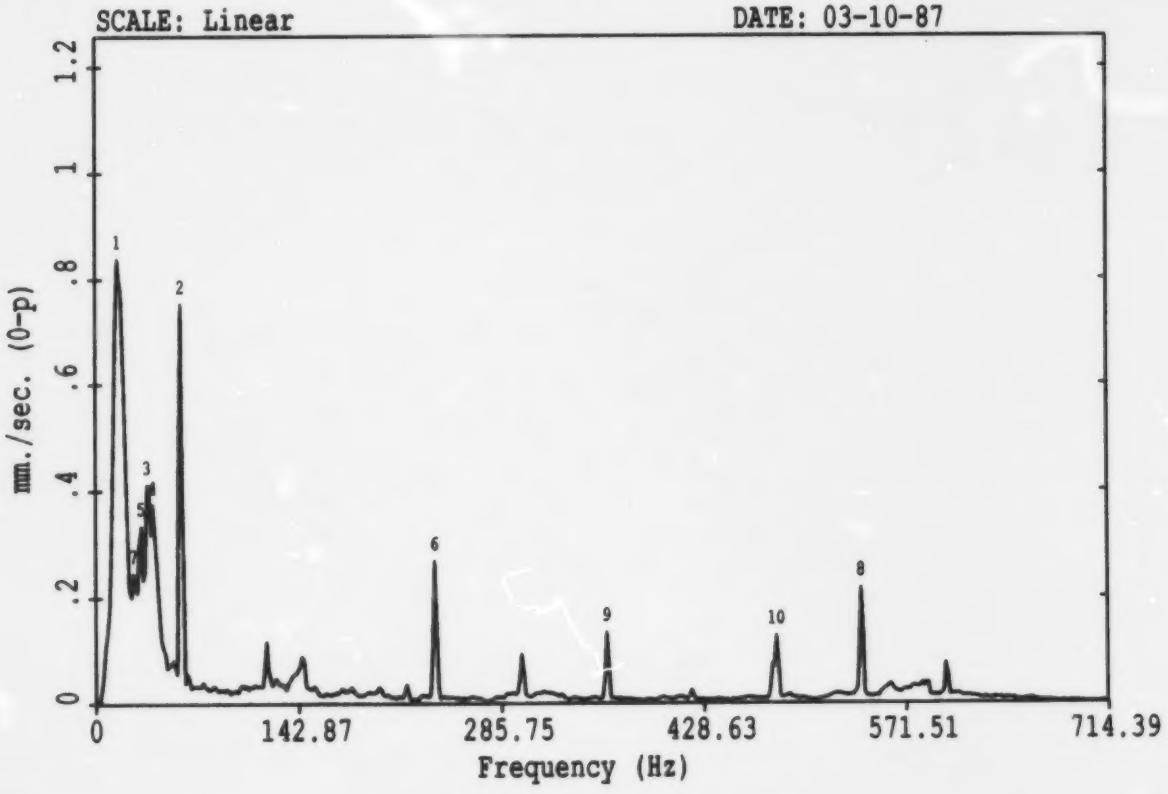

FIGURE 45

Darlington GS Standby Generator #4 Power Turbine

SIGNAL : Outboard Brg. Casing Velocity Horiz.
SPEED : 3600 r.p.m.
PROCESS CONDITION : Load 7 MW

PEAK NO.	FREQUENCY	ORDER	AMPLITUDE
1	60.0	1.00	2.23
2	18.1	0.30	1.56
3	238.6	3.98	0.70
4	120.0	2.00	0.48
5	55.8	0.93	0.43
6	32.1	0.53	0.37
7	27.9	0.47	0.35
8	300.0	5.00	0.25
9	108.8	1.81	0.24
10	47.4	0.79	0.23

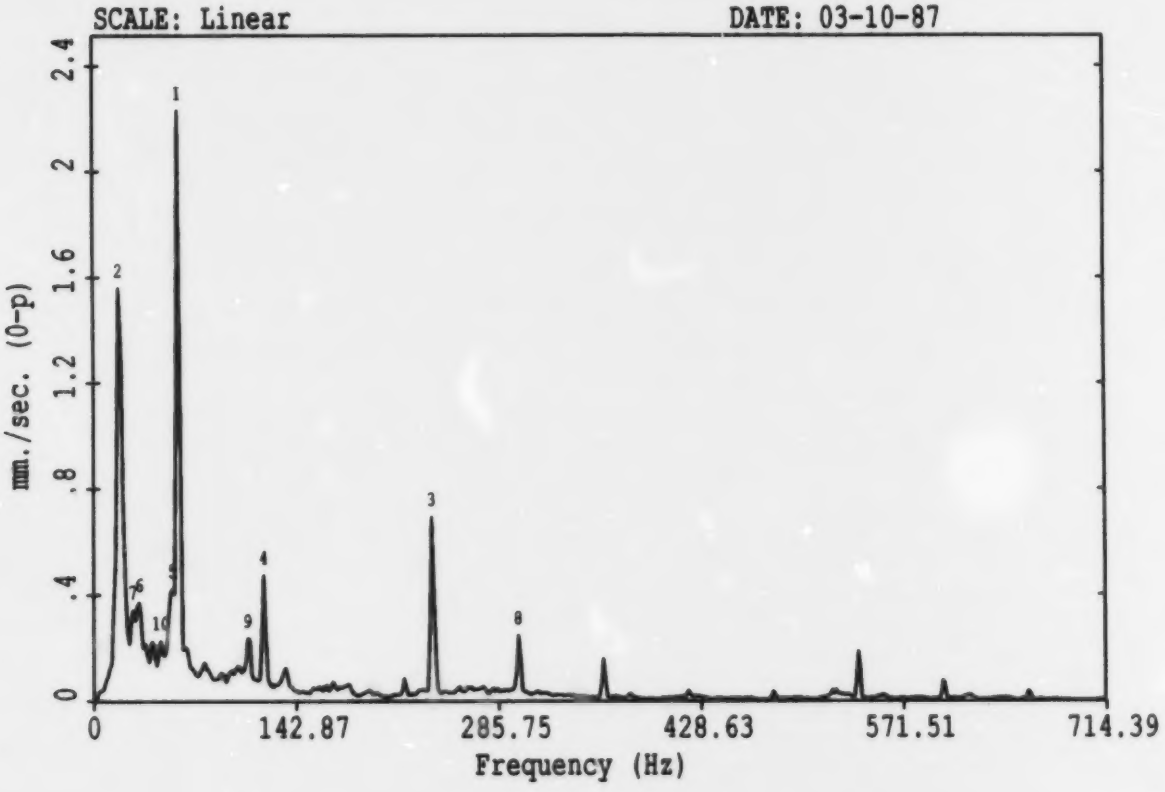

FIGURE 46

Darlington GS Standby Generator #4 Power Turbine

SIGNAL : Outboard Brg. Casing Velocity Vert.
SPEED : 3600 r.p.m.
PROCESS CONDITION : Load 7 MW

PEAK NO.	FREQUENCY	ORDER	AMPLITUDE
1	60.0	1.00	3.19
2	15.3	0.26	1.79
3	120.0	2.00	0.75
4	238.6	3.98	0.74
5	180.0	3.00	0.34
6	37.7	0.63	0.31
7	360.0	6.00	0.26
8	27.9	0.47	0.26
9	30.7	0.51	0.23
10	41.9	0.70	0.22

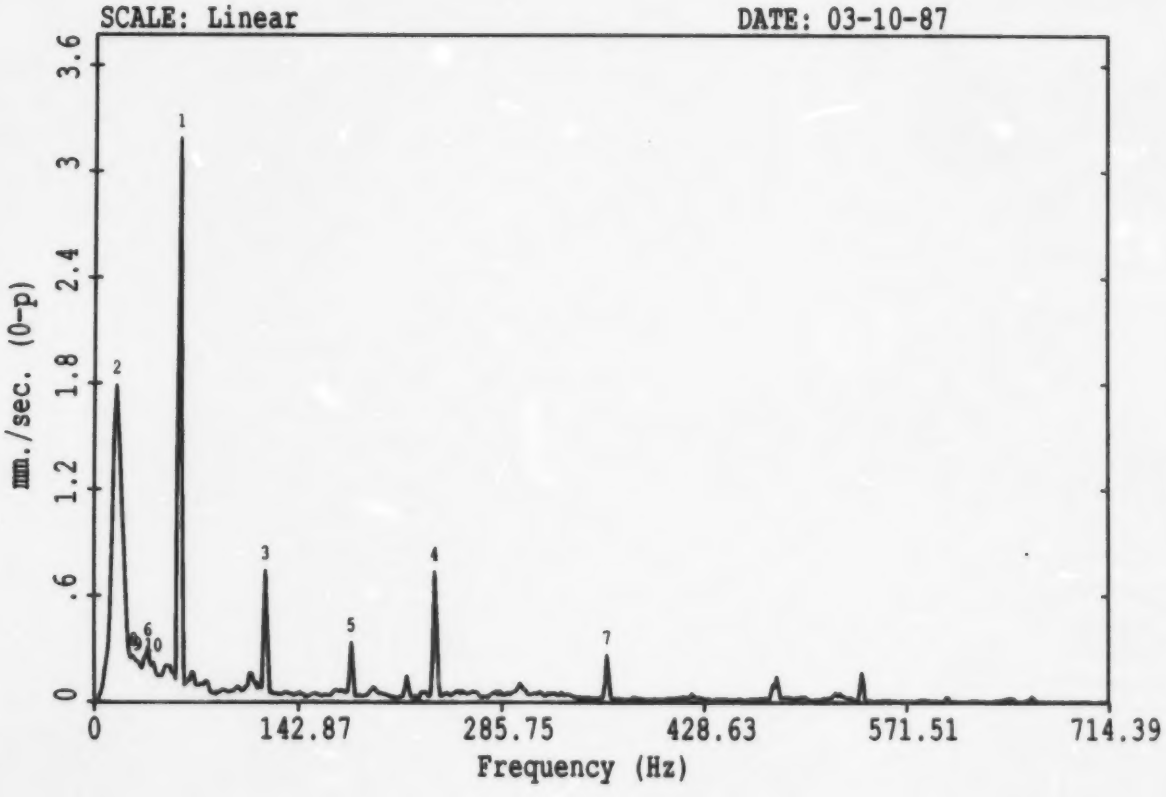

FIGURE 47

Darlington GS Standby Generator #4 Power Turbine

SIGNAL : Outboard Brg. Casing Velocity Axial
SPEED : 3600 r.p.m.
PROCESS CONDITION : Load 7 MW

PEAK NO.	FREQUENCY	ORDER	AMPLITUDE
1	15.3	0.26	1.24
2	60.0	1.00	0.70
3	36.3	0.60	0.48
4	40.5	0.67	0.42
5	32.1	0.53	0.26
6	26.5	0.44	0.23
7	120.0	2.00	0.18
8	540.0	9.00	0.17
9	480.0	8.00	0.17
10	47.4	0.79	0.14

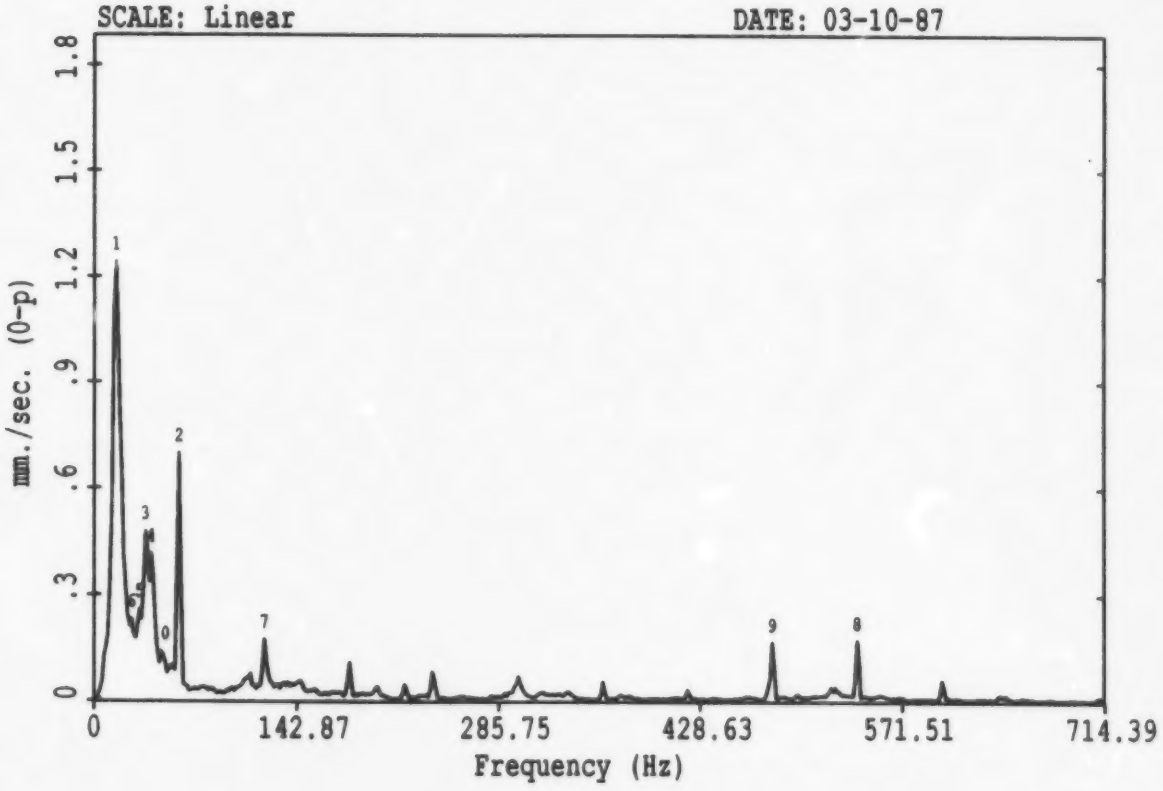

FIGURE 48

Darlington GS Standby Generator #4 Power Turbine

SIGNAL : Inboard Brg. Casing Velocity X-Axis
SPEED : 3600 r.p.m.
PROCESS CONDITION : Load 13 MW

PEAK NO.	FREQUENCY	ORDER	AMPLITUDE
1	60.0	1.00	1.76
2	19.5	0.33	0.70
3	15.3	0.26	0.50
4	48.8	0.81	0.25
5	115.8	1.93	0.22
6	238.6	3.98	0.22
7	29.3	0.49	0.18
8	64.2	1.07	0.16
9	25.1	0.42	0.15
10	44.6	0.74	0.15

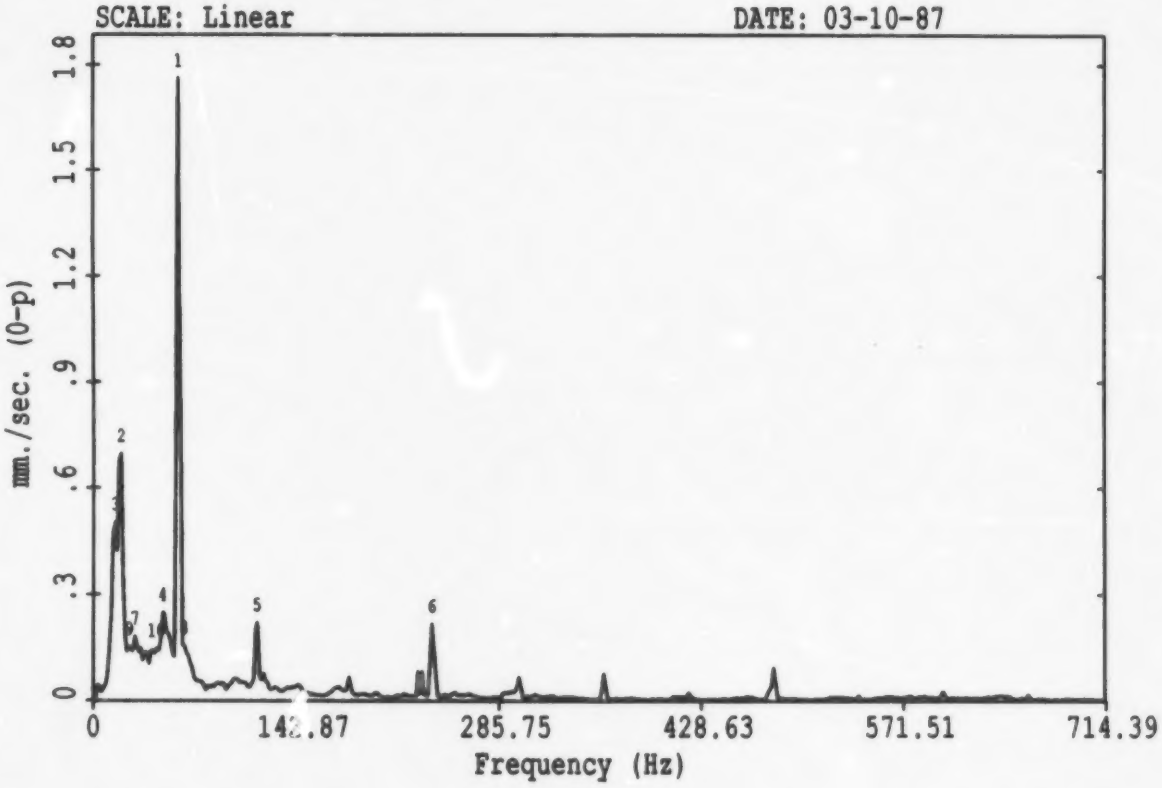

FIGURE 49

Darlington GS Standby Generator #4 Power Turbine

SIGNAL : Inboard Brg. Casing Velocity Y-Axis
SPEED : 3600 r.p.m.
PROCESS CONDITION : Load 13 MW

PEAK NO.	FREQUENCY	ORDER	AMPLITUDE
1	60.0	1.00	1.59
2	15.3	0.26	0.38
3	54.4	0.91	0.38
4	50.2	0.84	0.32
5	120.0	2.00	0.24
6	32.1	0.53	0.22
7	44.6	0.74	0.18
8	64.2	1.07	0.18
9	37.7	0.63	0.16
10	25.1	0.42	0.15

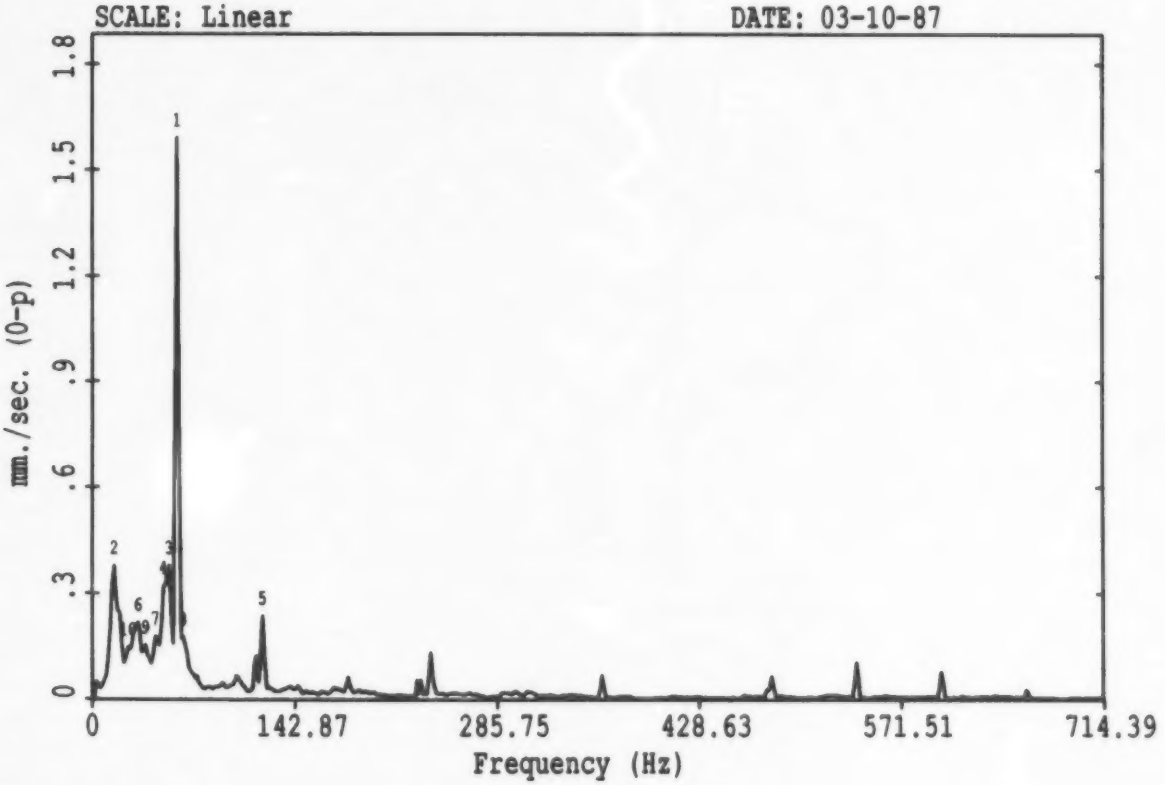

FIGURE 50

Darlington GS Standby Generator #4 Power Turbine

SIGNAL : Inboard Brg. Casing Velocity Axial
SPEED : 3600 r.p.m.
PROCESS CONDITION : Load 13 MW

PEAK NO.	FREQUENCY	ORDER	AMPLITUDE
1	15.3	0.26	0.83
2	60.0	1.00	0.79
3	19.5	0.33	0.60
4	37.7	0.63	0.48
5	40.5	0.67	0.46
6	32.1	0.53	0.32
7	44.6	0.74	0.23
8	540.0	9.00	0.20
9	238.6	3.98	0.18
10	26.5	0.44	0.17

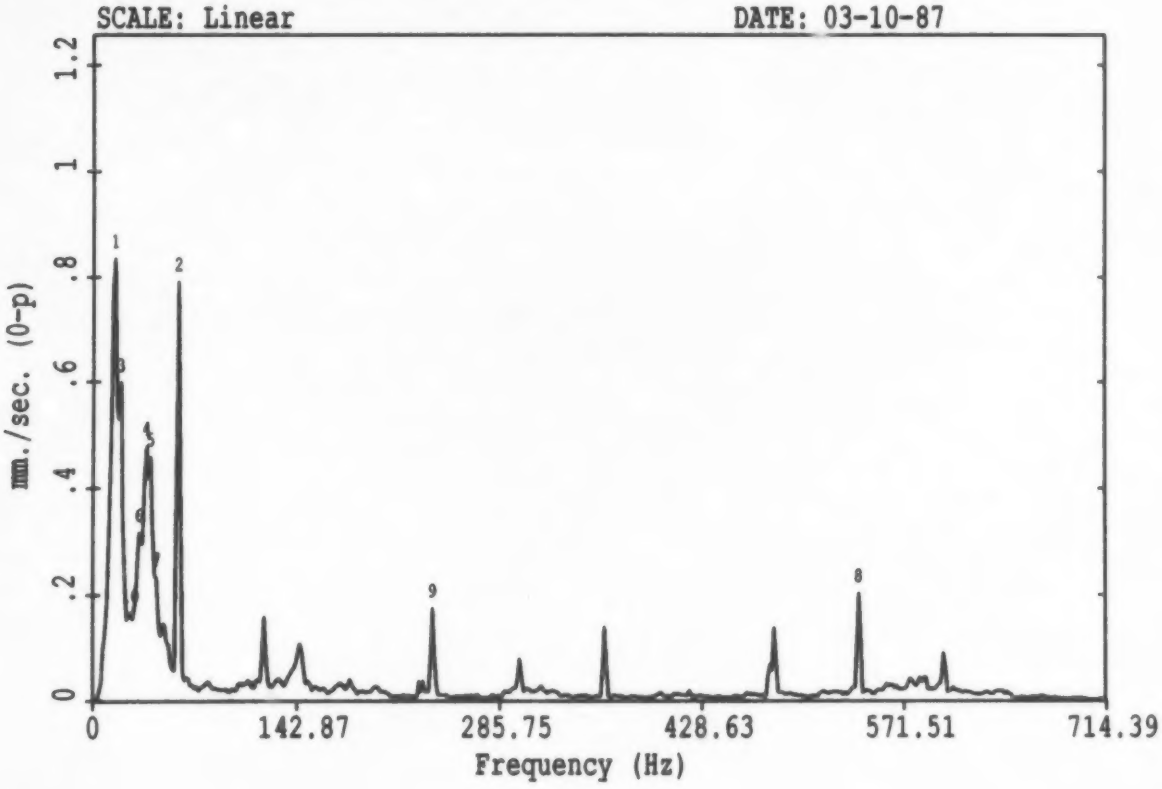

FIGURE 51

Darlington GS Standby Generator #4 Power Turbine

SIGNAL : Outboard Brg. Casing Velocity Horiz.
SPEED : 3600 r.p.m.
PROCESS CONDITION : Load 13 MW

PEAK NO.	FREQUENCY	ORDER	AMPLITUDE
1	60.0	1.00	2.32
2	19.5	0.33	1.06
3	238.6	3.98	0.61
4	120.0	2.00	0.43
5	30.7	0.51	0.41
6	300.0	5.00	0.25
7	47.4	0.79	0.25
8	64.2	1.07	0.24
9	114.4	1.91	0.21
10	540.0	9.00	0.20

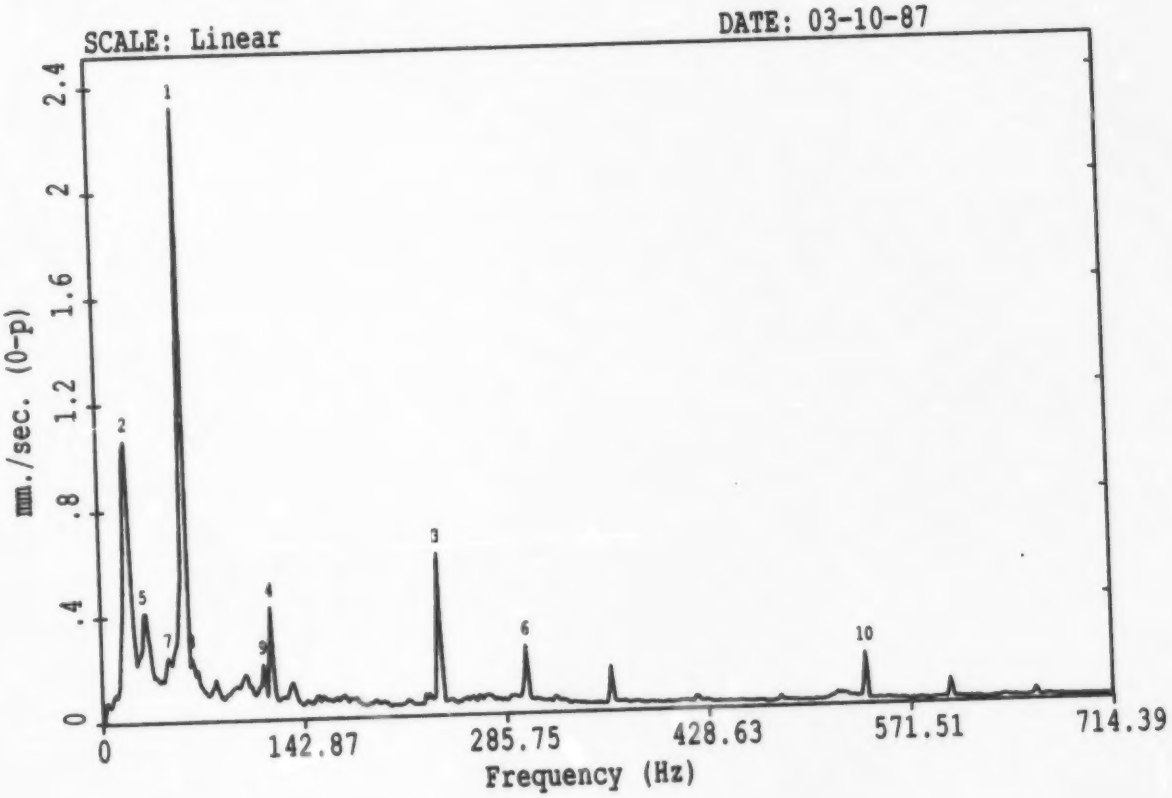

FIGURE 52

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Darlington GS Standby Generator #4 Power Turbine

SIGNAL : Outboard Brg. Casing Velocity Vert.
SPEED : 3600 r.p.m.
PROCESS CONDITION : Load 13 MW

PEAK NO.	FREQUENCY	ORDER	AMPLITUDE
1	60.0	1.00	2.76
2	15.3	0.26	1.81
3	19.5	0.33	1.06
4	120.0	2.00	0.80
5	238.6	3.98	0.46
6	50.2	0.84	0.40
7	180.0	3.00	0.39
8	37.7	0.63	0.32
9	25.1	0.42	0.30
10	360.0	6.00	0.27

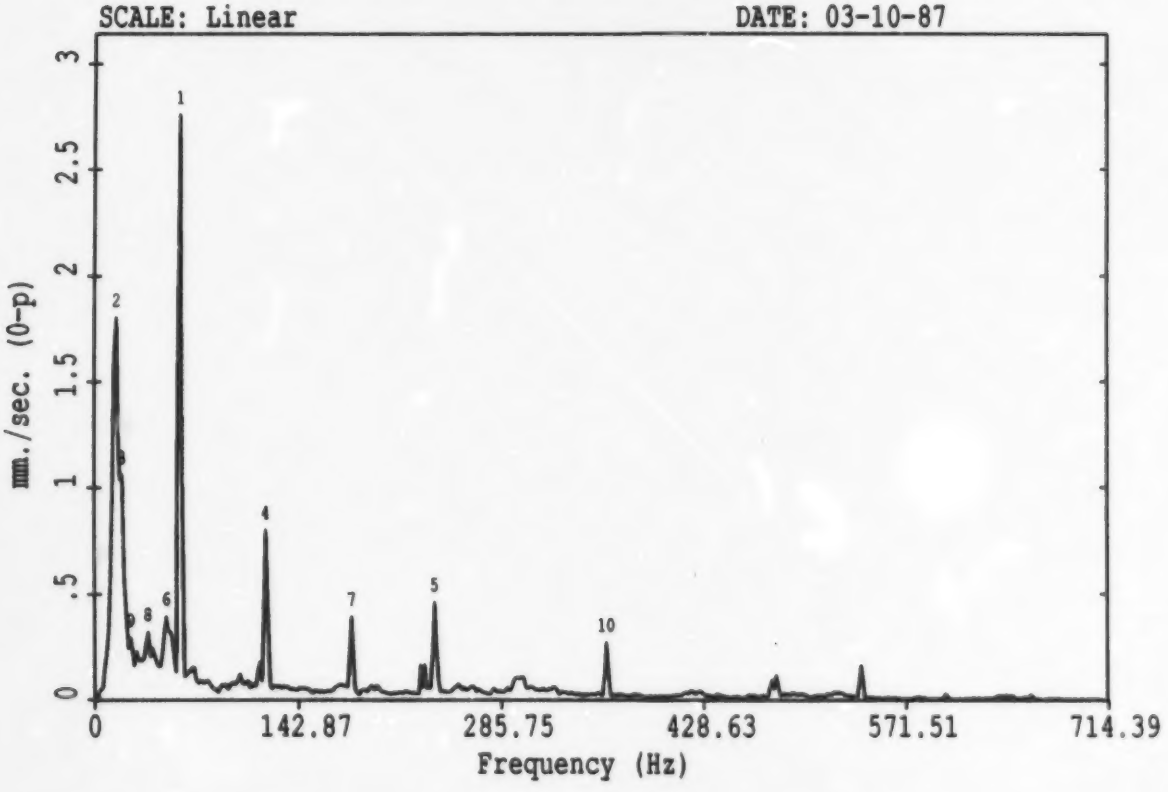

FIGURE 53

Darlington GS Standby Generator #4 Power Turbine

SIGNAL : Outboard Brg. Casing Velocity Axial
SPEED : 3600 r.p.m.
PROCESS CONDITION : Load 13 MW

PEAK NO.	FREQUENCY	ORDER	AMPLITUDE
1	14.0	0.23	0.83
2	60.0	1.00	0.64
3	19.5	0.33	0.58
4	36.3	0.60	0.43
5	39.1	0.65	0.39
6	43.3	0.72	0.31
7	120.0	2.00	0.19
8	540.0	9.00	0.17
9	48.8	0.81	0.16
10	480.0	8.00	0.16

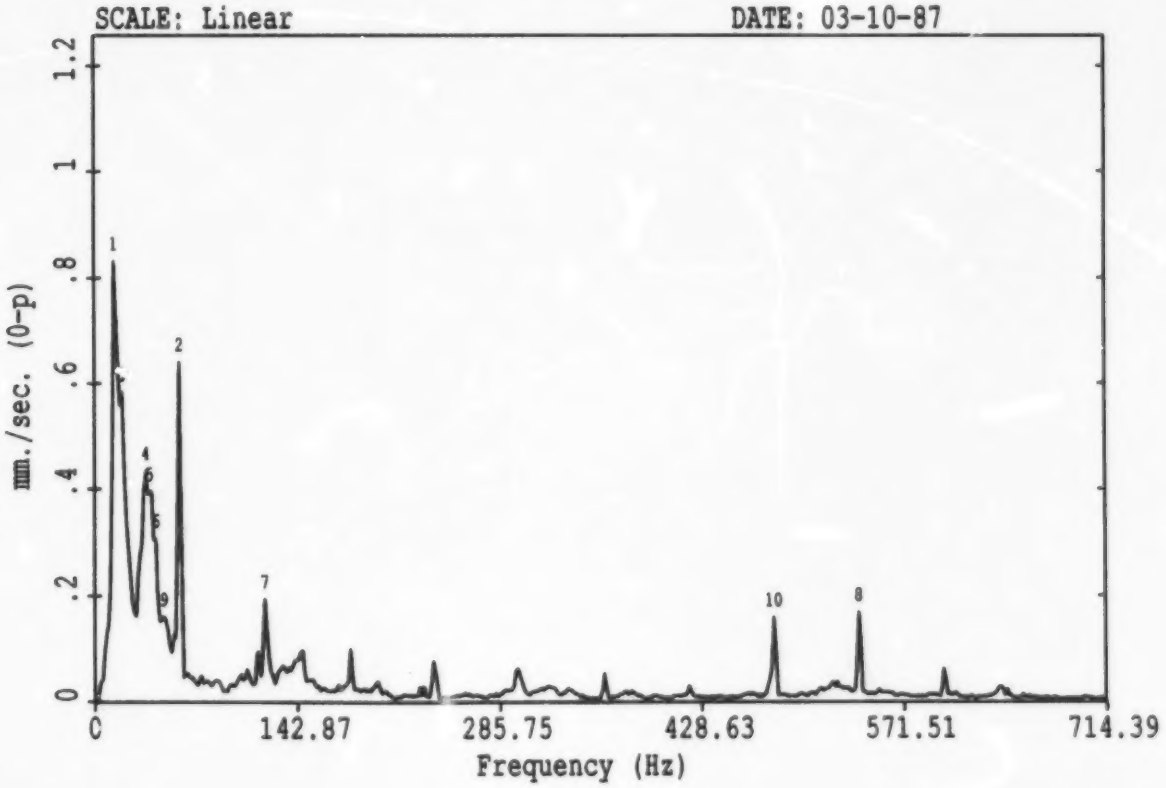

FIGURE 54

Darlington GS Standby Generator #4 Power Turbine

SIGNAL : Inboard Brg. Casing Velocity X-Axis
SPEED : 3600 r.p.m.
PROCESS CONDITION : Load 20 MW

PEAK NO.	FREQUENCY	ORDER	AMPLITUDE
1	60.0	1.00	2.30
2	18.1	0.30	0.56
3	15.3	0.26	0.48
4	238.6	3.98	0.19
5	32.1	0.53	0.18
6	120.0	2.00	0.17
7	26.5	0.44	0.15
8	67.0	1.12	0.15
9	99.1	1.65	0.13
10	36.3	0.60	0.13

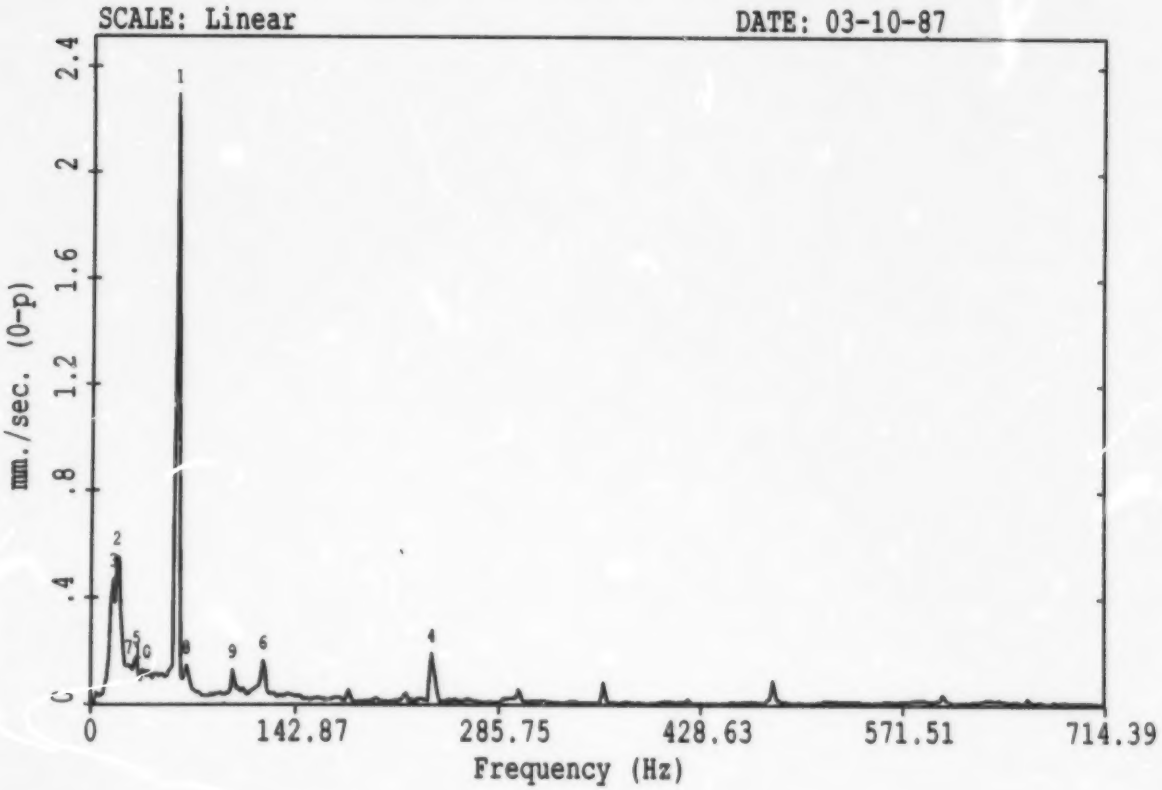

FIGURE 55

Darlington GS Standby Generator #4 Power Turbine

SIGNAL : Inboard Brg. Casing Velocity Y-Axis
SPEED : 3600 r.p.m.
PROCESS CONDITION : Load 20 MW

PEAK NO.	FREQUENCY	ORDER	AMPLITUDE
1	60.0	1.00	2.36
2	15.3	0.26	0.43
3	32.1	0.53	0.28
4	120.0	2.00	0.21
5	26.5	0.44	0.17
6	241.4	4.02	0.16
7	46.0	0.77	0.15
8	67.0	1.12	0.14
9	37.7	0.63	0.12
10	360.0	6.00	0.11

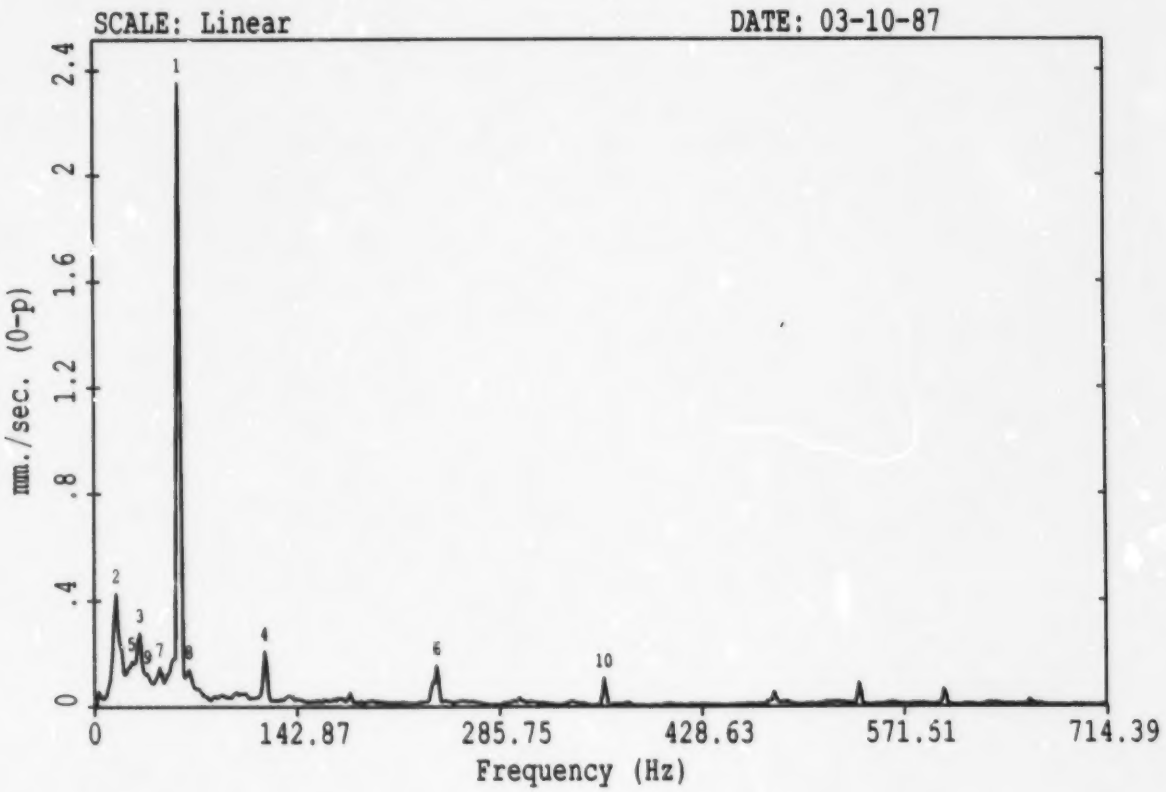

FIGURE 56

Darlington GS Standby Generator #4 Power Turbine

SIGNAL : Inboard Brg. Casing Velocity Axial
SPEED : 3600 r.p.m.
PROCESS CONDITION : Load 20 MW

PEAK NO.	FREQUENCY	ORDER	AMPLITUDE
1	15.3	0.26	0.88
2	60.0	1.00	0.73
3	40.5	0.67	0.51
4	37.7	0.63	0.46
5	32.1	0.53	0.33
6	540.0	9.00	0.18
7	48.8	0.81	0.17
8	120.0	2.00	0.16
9	360.0	6.00	0.16
10	238.6	3.98	0.14

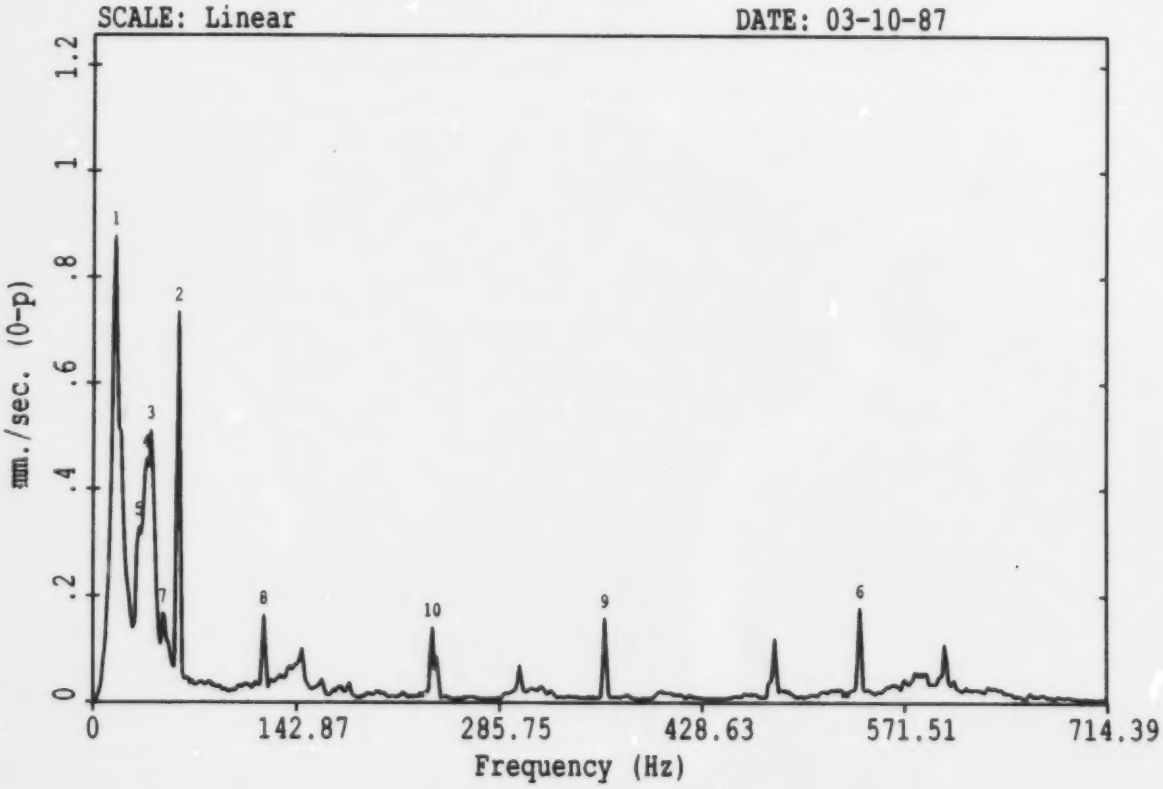

FIGURE 57

Darlington GS Standby Generator #4 Power Turbine

SIGNAL : Outboard Brg. Casing Velocity Horiz.
SPEED : 3600 r.p.m.
PROCESS CONDITION : Load 20 MW

PEAK NO.	FREQUENCY	ORDER	AMPLITUDE
1	60.0	1.00	2.18
2	19.5	0.33	1.10
3	238.6	3.98	0.80
4	120.0	2.00	0.55
5	32.1	0.53	0.42
6	26.5	0.44	0.25
7	300.0	5.00	0.22
8	54.4	0.91	0.18
9	50.2	0.84	0.17
10	540.0	9.00	0.17

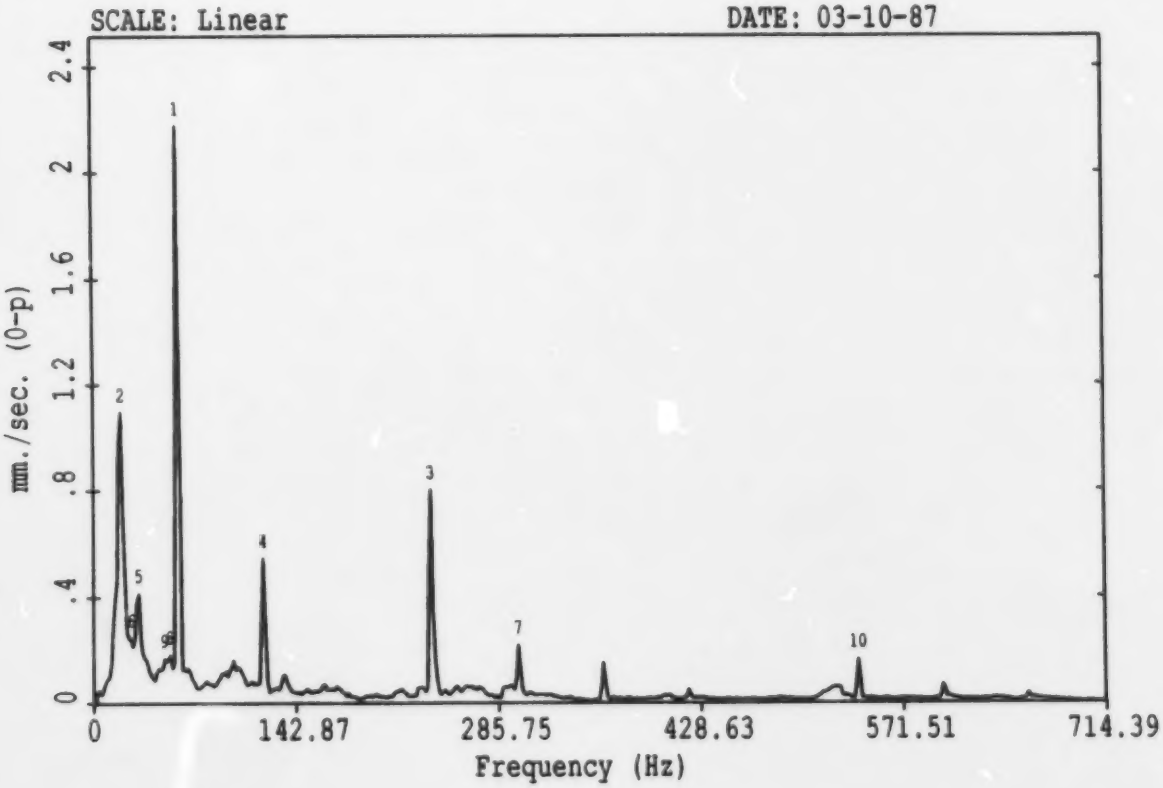

FIGURE 58

Darlington GS Standby Generator #4 Power Turbine

SIGNAL : Outboard Brg. Casing Velocity Vert.
SPEED : 3600 r.p.m.
PROCESS CONDITION : Load 20 MW

PEAK NO.	FREQUENCY	ORDER	AMPLITUDE
1	60.0	1.00	2.63
2	15.3	0.26	1.94
3	120.0	2.00	0.88
4	180.0	3.00	0.39
5	238.6	3.98	0.36
6	40.5	0.67	0.28
7	241.4	4.02	0.27
8	32.1	0.53	0.26
9	360.0	6.00	0.25
10	37.7	0.63	0.25

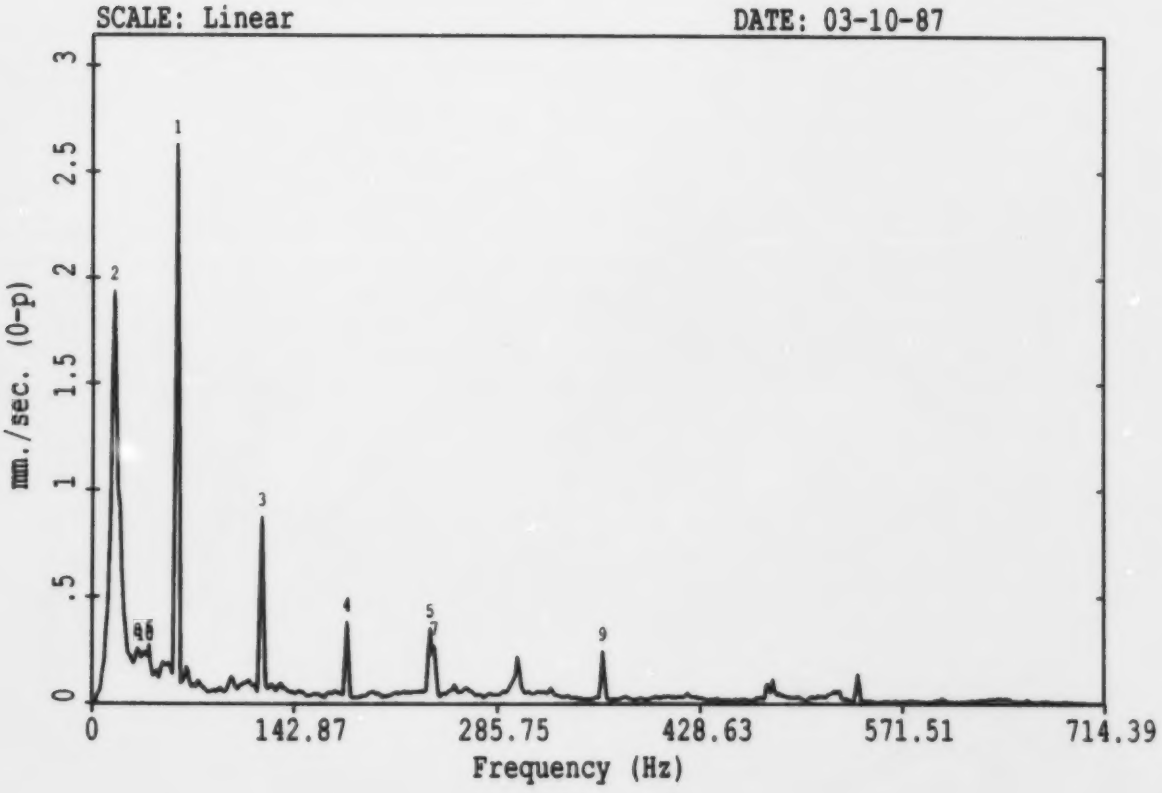

FIGURE 59

Darlington GS Standby Generator #4 Power Turbine

SIGNAL : Outboard Brg. Casing Velocity Axial
SPEED : 3600 r.p.m.
PROCESS CONDITION : Load 20 MW

PEAK NO.	FREQUENCY	ORDER	AMPLITUDE
1	15.3	0.26	0.91
2	19.5	0.33	0.57
3	60.0	1.00	0.54
4	40.5	0.67	0.49
5	37.7	0.63	0.42
6	32.1	0.53	0.32
7	48.8	0.81	0.17
8	120.0	2.00	0.17
9	480.0	8.00	0.16
10	540.0	9.00	0.14

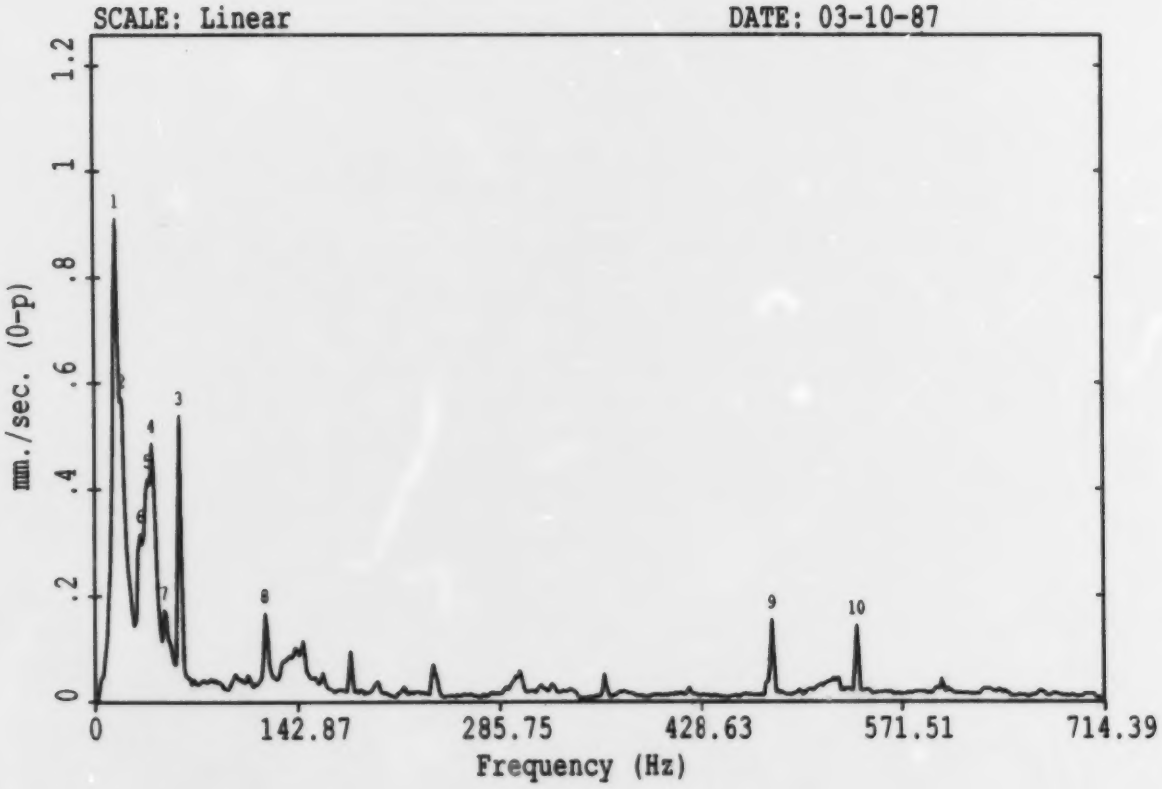

FIGURE 60

Darlington GS Standby Generator #4 Power Turbine

SIGNAL : Inboard Brg. Casing Velocity X-Axis
SPEED : 3600 r.p.m.
PROCESS CONDITION : Load 26 MW

PEAK NO.	FREQUENCY	ORDER	AMPLITUDE
1	60.0	1.00	2.17
2	15.3	0.26	0.56
3	18.1	0.30	0.47
4	30.7	0.51	0.20
5	238.6	3.98	0.19
6	124.2	2.07	0.18
7	23.7	0.40	0.17
8	120.0	2.00	0.16
9	43.3	0.72	0.16
10	36.3	0.60	0.15

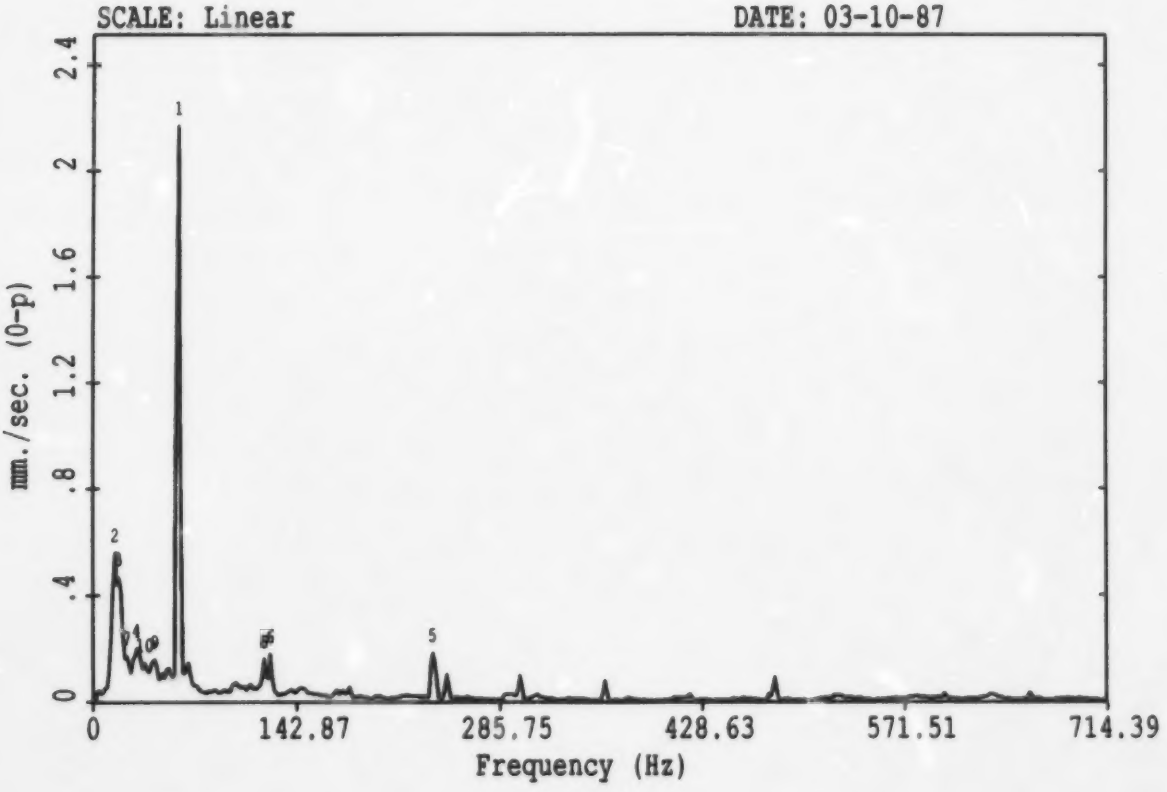

FIGURE 61

Darlington GS Standby Generator #4 Power Turbine

SIGNAL : Inboard Brg. Casing Velocity Y-Axis
SPEED : 3600 r.p.m.
PROCESS CONDITION : Load 26 MW

PEAK NO.	FREQUENCY	ORDER	AMPLITUDE
1	60.0	1.00	2.56
2	15.3	0.26	0.46
3	30.7	0.51	0.30
4	23.7	0.40	0.21
5	120.0	2.00	0.19
6	65.6	1.09	0.16
7	124.2	2.07	0.13
8	55.8	0.93	0.13
9	248.4	4.14	0.11
10	44.6	0.74	0.11

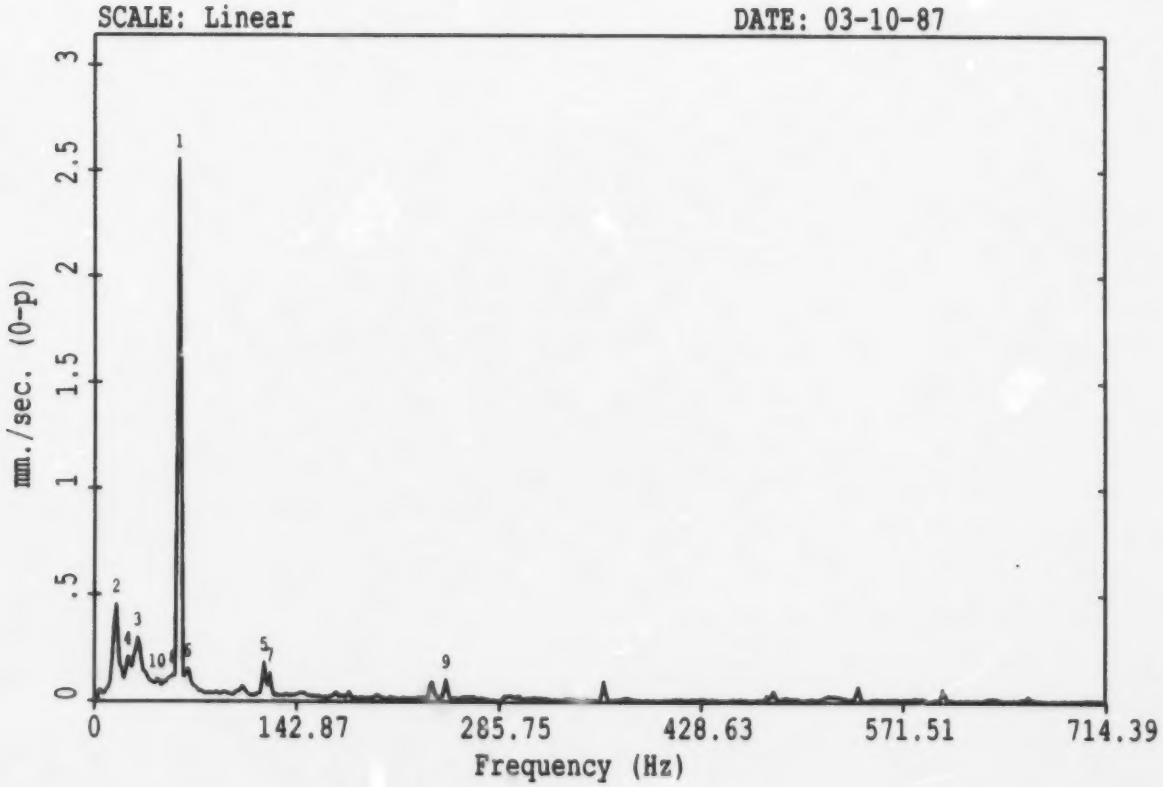

FIGURE 62

Darlington GS Standby Generator #4 Power Turbine

SIGNAL : Inboard Brg. Casing Velocity Axial
SPEED : 3600 r.p.m.
PROCESS CONDITION : Load 26 MW

PEAK NO.	FREQUENCY	ORDER	AMPLITUDE
1	15.3	0.26	0.99
2	60.0	1.00	0.64
3	36.3	0.60	0.61
4	40.5	0.67	0.49
5	29.3	0.49	0.29
6	120.0	2.00	0.17
7	8.4	0.14	0.16
8	238.6	3.98	0.16
9	360.0	6.00	0.15
10	51.6	0.86	0.14

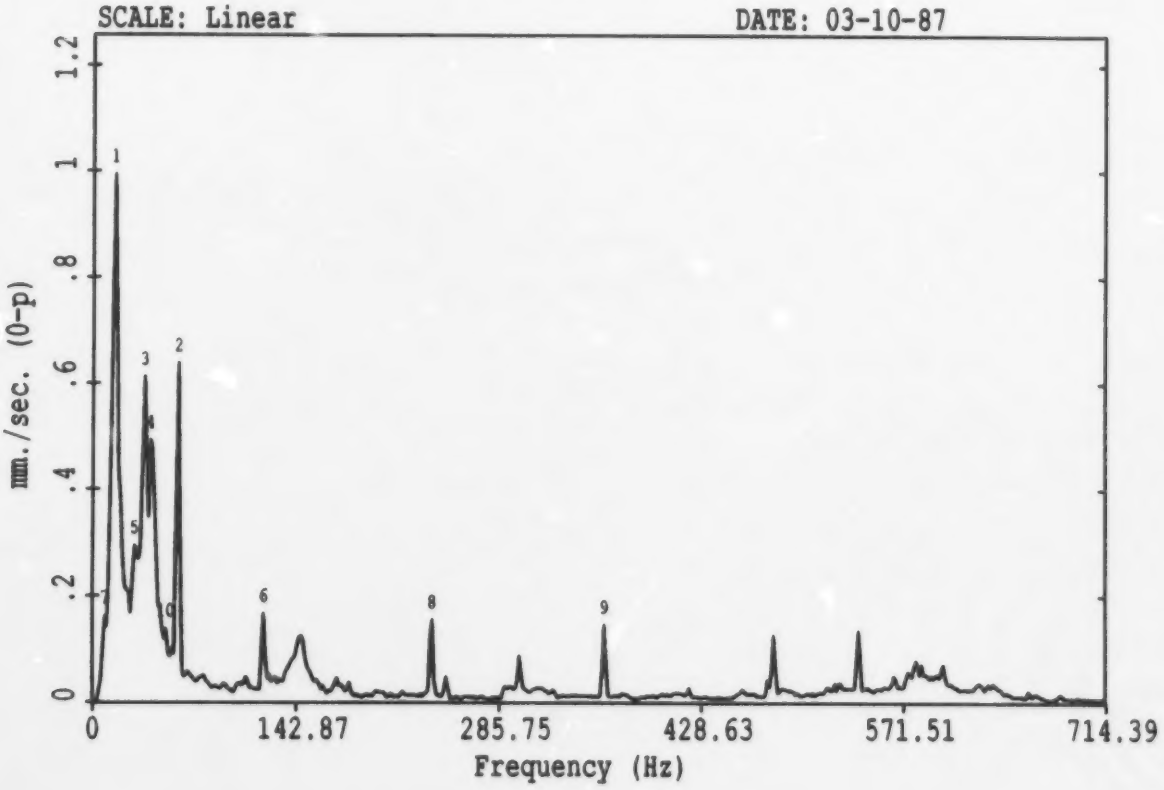

FIGURE 63

Darlington GS Standby Generator #4 Power Turbine

SIGNAL : Outboard Brg. Casing Velocity Horiz.
SPEED : 3600 r.p.m.
PROCESS CONDITION : Load 26 MW

PEAK NO.	FREQUENCY	ORDER	AMPLITUDE
1	60.0	1.00	2.13
2	19.5	0.33	0.83
3	120.0	2.00	0.62
4	238.6	3.98	0.53
5	30.7	0.51	0.44
6	300.0	5.00	0.25
7	248.4	4.14	0.23
8	67.0	1.12	0.17
9	360.0	6.00	0.15
10	540.0	9.00	0.15

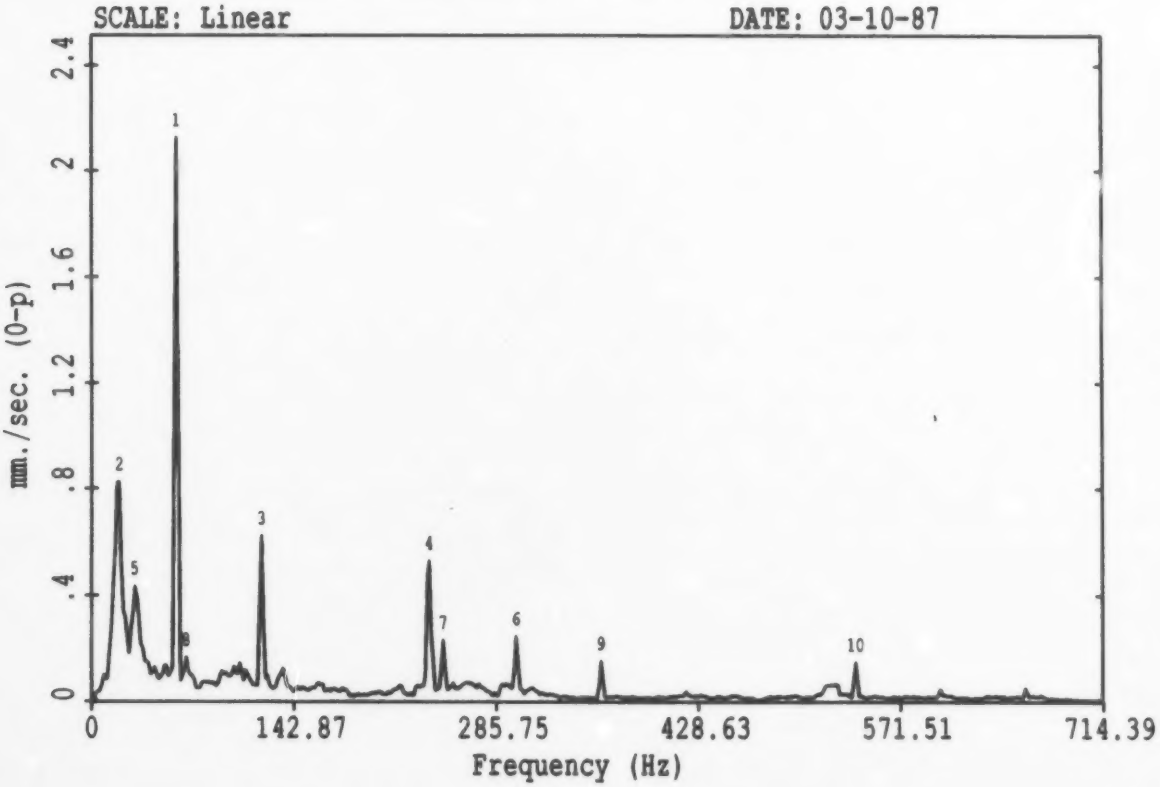

FIGURE 64

Darlington GS Standby Generator #4 Power Turbine

SIGNAL : Outboard Brg. Casing Velocity Vert.
SPEED : 3600 r.p.m.
PROCESS CONDITION : Load 26 MW

PEAK NO.	FREQUENCY	ORDER	AMPLITUDE
1	60.0	1.00	2.59
2	15.3	0.26	2.14
3	120.0	2.00	0.92
4	180.0	3.00	0.41
5	300.0	5.00	0.37
6	238.6	3.98	0.37
7	25.1	0.42	0.33
8	36.3	0.60	0.32
9	30.7	0.51	0.31
10	248.4	4.14	0.31

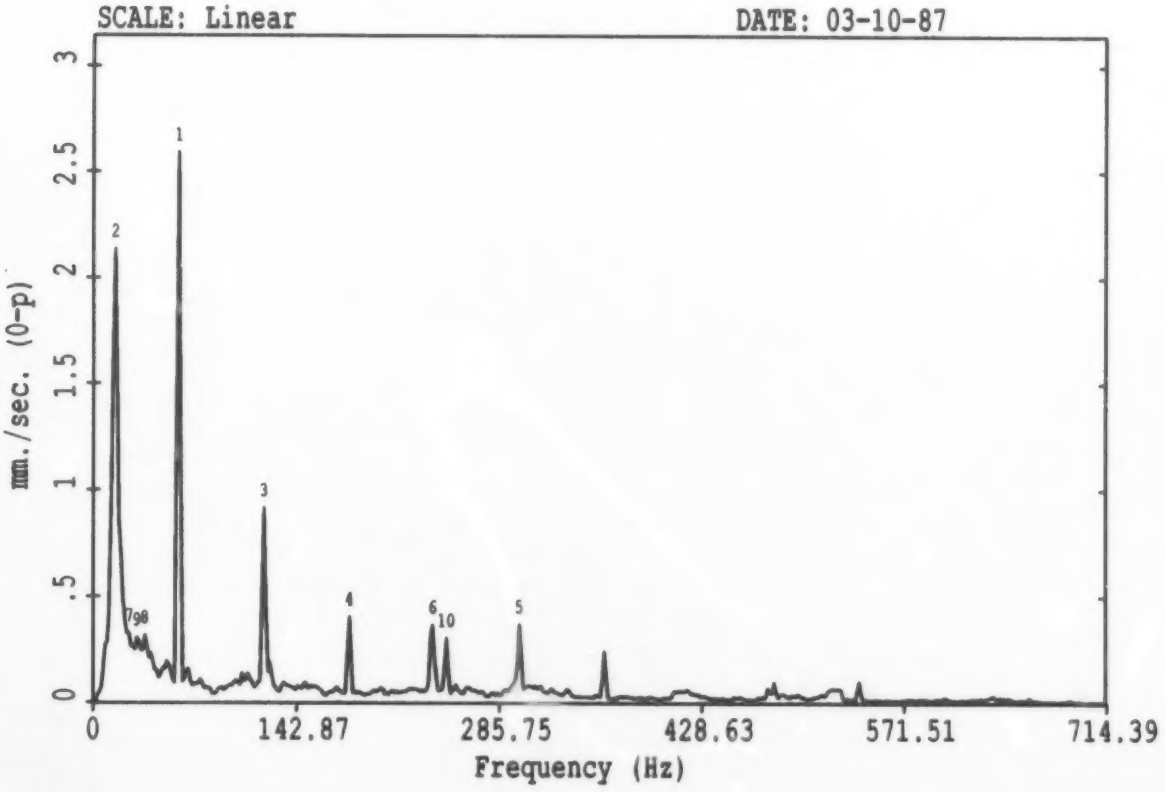

FIGURE 65

Darlington GS Standby Generator #4 Power Turbine

SIGNAL : Outboard Brg. Casing Velocity Axial
SPEED : 3600 r.p.m.
PROCESS CONDITION : Load 26 MW

PEAK NO.	FREQUENCY	ORDER	AMPLITUDE
1	15.3	0.26	1.03
2	36.3	0.60	0.57
3	60.0	1.00	0.49
4	40.5	0.67	0.47
5	29.3	0.49	0.30
6	8.4	0.14	0.17
7	143.7	2.40	0.16
8	120.0	2.00	0.15
9	480.0	8.00	0.15
10	139.5	2.33	0.14

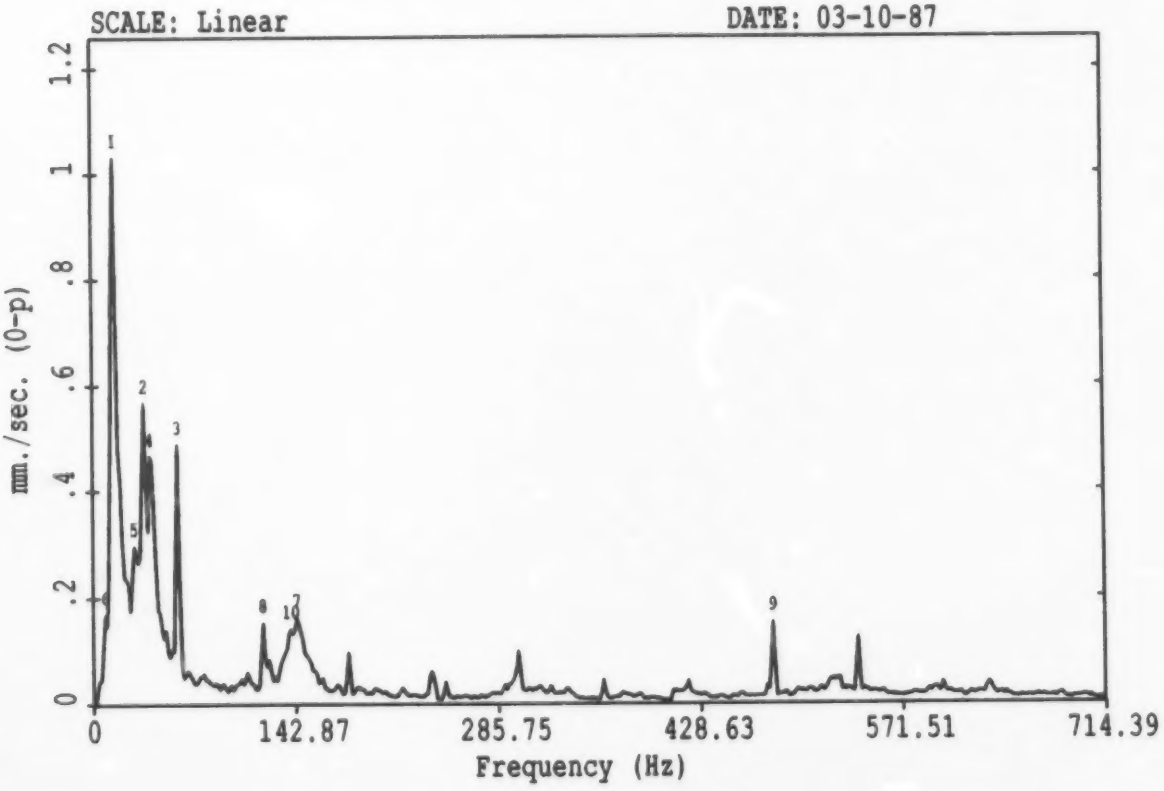

FIGURE 66

Darlington GS Standby Generator #4 AC Generator

SIGNAL : Outboard Brg. Shaft Displacement X-Axis
SPEED : 3600 r.p.m.
PROCESS CONDITION : Load 0 MW

PEAK NO.	FREQUENCY	ORDER	AMPLITUDE
1	60.0	1.00	8.20
2	240.0	4.00	4.44
3	120.0	2.00	2.63
4	300.0	5.00	2.56
5	480.0	8.00	2.23
6	540.0	9.00	1.77
7	180.0	3.00	1.75
8	420.0	7.00	0.91
9	600.0	10.00	0.48
10	660.0	11.00	0.47

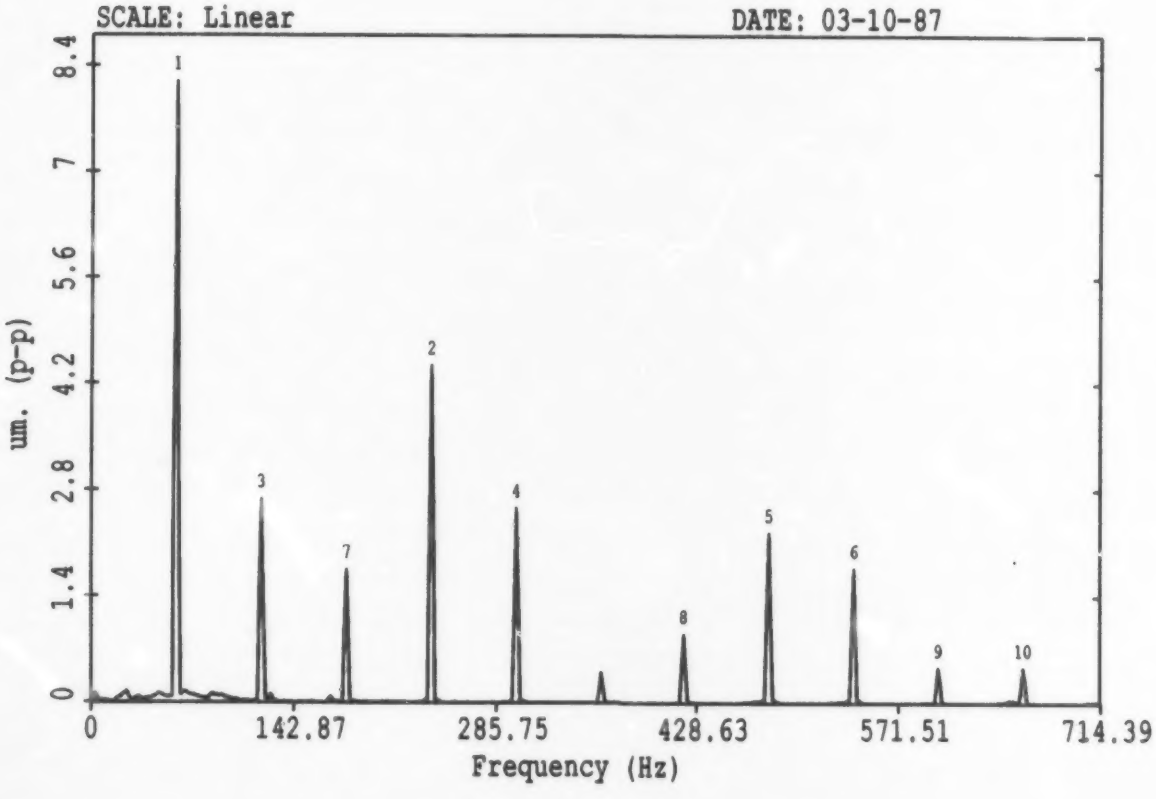

FIGURE 67

Darlington GS Standby Generator #4 AC Generator

SIGNAL : Outboard Brg. Shaft Displacement Y-Axis
SPEED : 3600 r.p.m.
PROCESS CONDITION : Load 0 MW

PEAK NO.	FREQUENCY	ORDER	AMPLITUDE
1	60.0	1.00	13.10
2	240.0	4.00	3.73
3	120.0	2.00	3.46
4	480.0	8.00	2.32
5	180.0	3.00	2.13
6	300.0	5.00	1.92
7	540.0	9.00	1.65
8	420.0	7.00	1.04
9	600.0	10.00	0.60
10	660.0	11.00	0.55

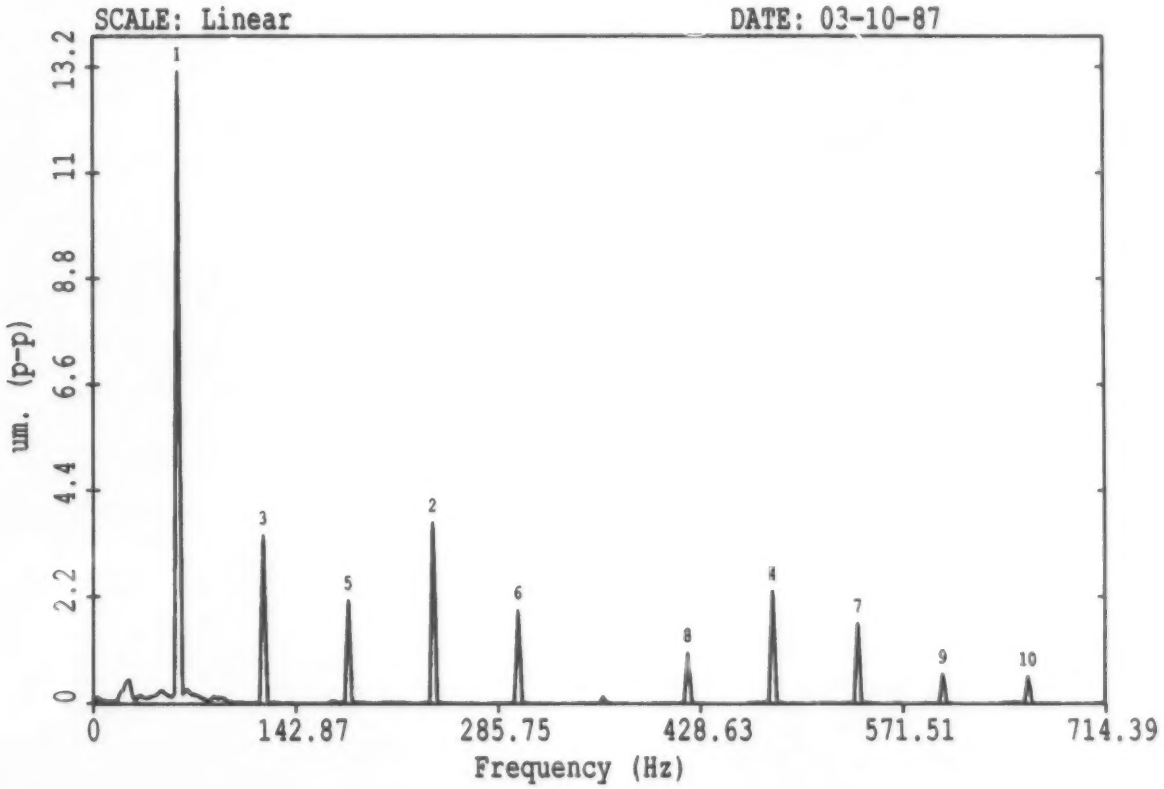

FIGURE 68

Darlington GS Standby Generator #4 AC Generator

SIGNAL : Inboard Brg. Shaft Displacement X-Axis
SPEED : 3600 r.p.m.
PROCESS CONDITION : Load 0 MW

PEAK NO.	FREQUENCY	ORDER	AMPLITUDE
1	60.0	1.00	7.33
2	240.0	4.00	5.77
3	480.0	8.00	4.33
4	180.0	3.00	3.98
5	120.0	2.00	3.48
6	300.0	5.00	3.43
7	420.0	7.00	2.51
8	540.0	9.00	2.03
9	660.0	11.00	1.12
10	600.0	10.00	1.04

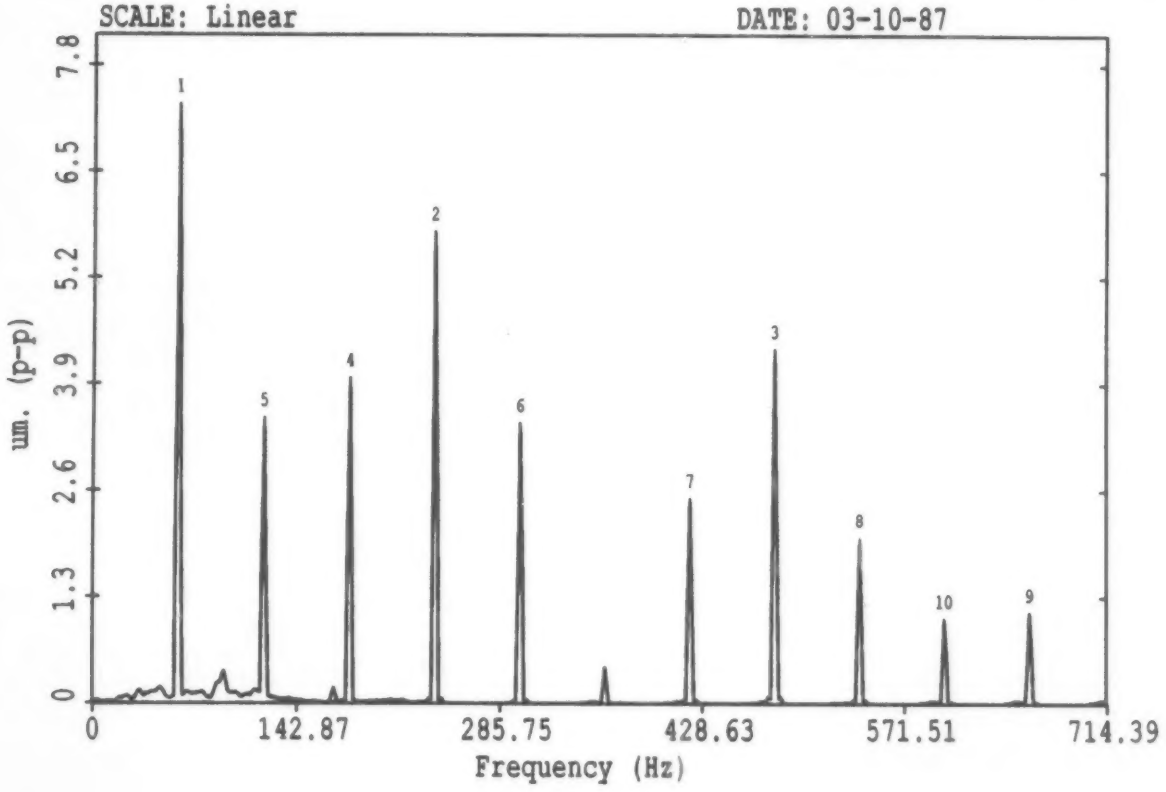

FIGURE 69

Darlington GS Standby Generator #4 AC Generator

SIGNAL : Inboard Brg. Shaft Displacement Y-Axis
SPEED : 3600 r.p.m.
PROCESS CONDITION : Load 0 MW

PEAK NO.	FREQUENCY	ORDER	AMPLITUDE
1	60.0	1.00	5.83
2	240.0	4.00	4.67
3	480.0	8.00	3.20
4	180.0	3.00	3.05
5	300.0	5.00	2.79
6	420.0	7.00	2.07
7	120.0	2.00	1.60
8	660.0	11.00	1.41
9	540.0	9.00	1.21
10	600.0	10.00	1.16

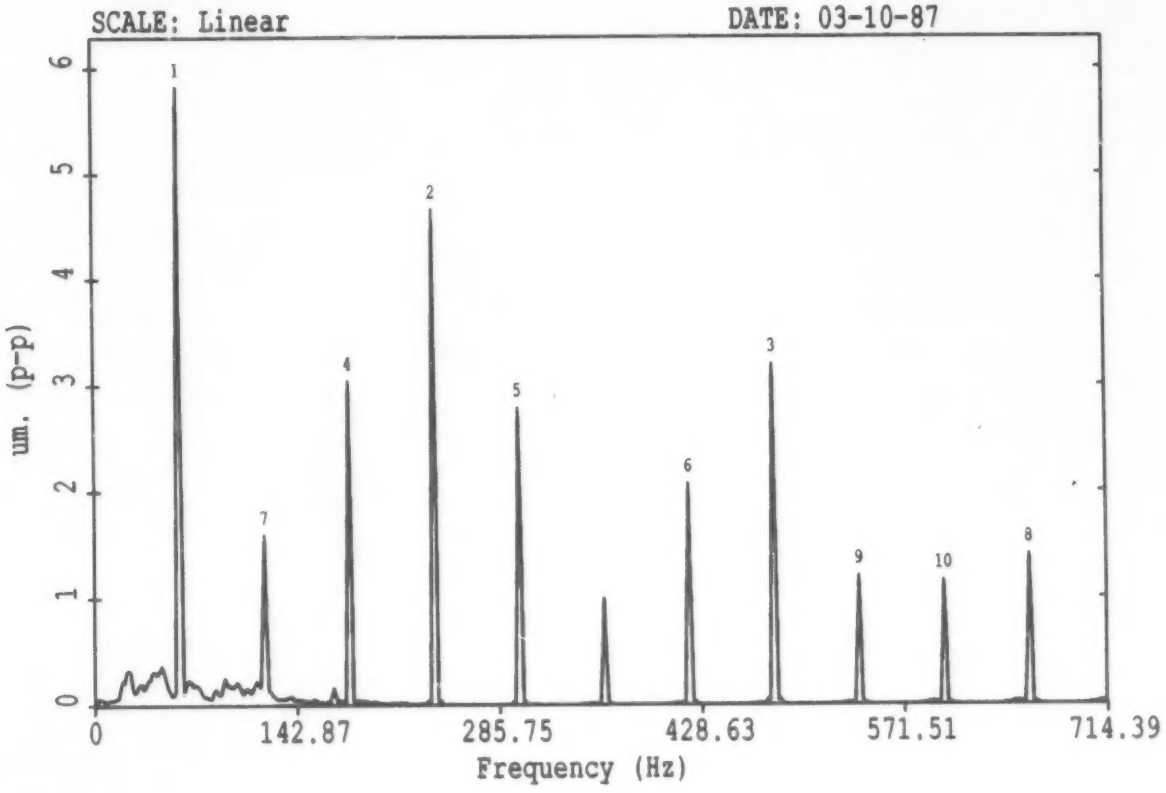

FIGURE 70

Darlington GS Standby Generator #4 AC Generator

SIGNAL : Outboard Brg. Shaft Displacement X-Axis
SPEED : 3600 r.p.m.
PROCESS CONDITION : Load 7 MW

PEAK NO.	FREQUENCY	ORDER	AMPLITUDE
1	60.0	1.00	8.68
2	240.0	4.00	4.35
3	300.0	5.00	2.51
4	120.0	2.00	2.49
5	480.0	8.00	2.22
6	180.0	3.00	1.78
7	540.0	9.00	1.74
8	420.0	7.00	0.94
9	600.0	10.00	0.49
10	660.0	11.00	0.48

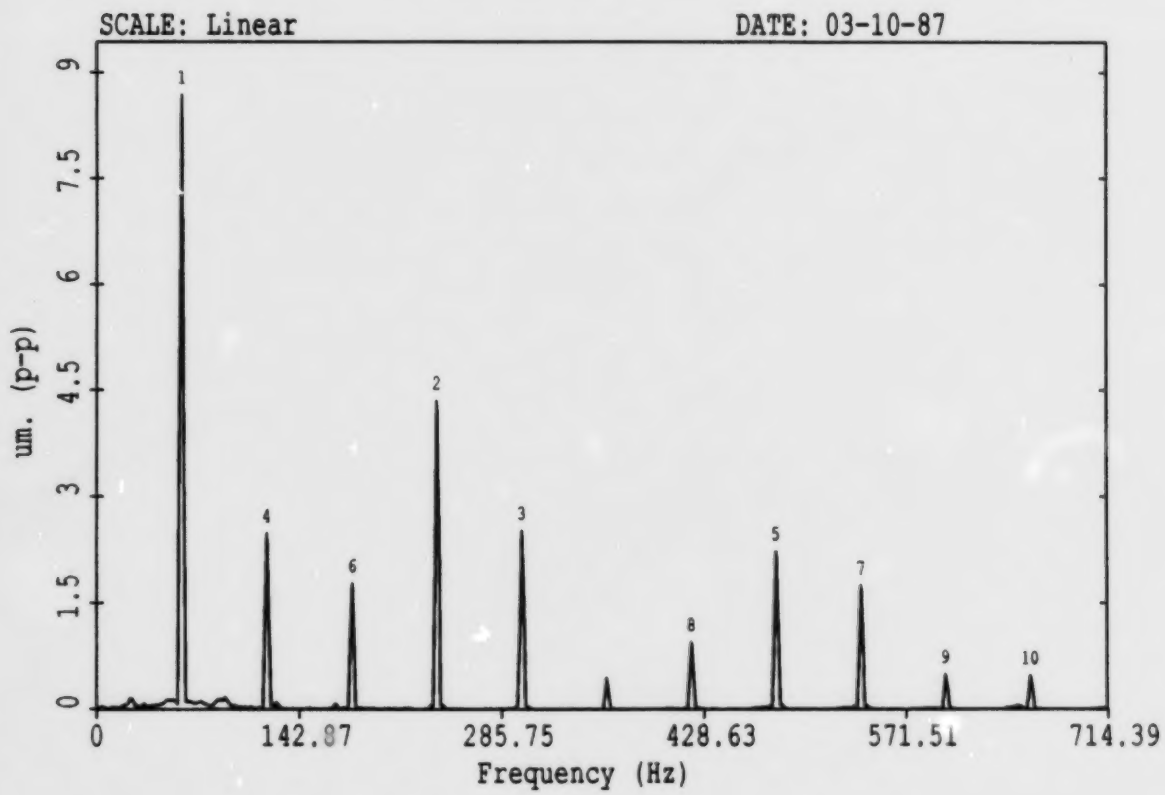

FIGURE 71

Darlington GS Standby Generator #4 AC Generator

SIGNAL : Outboard Brg. Shaft Displacement Y-Axis
SPEED : 3600 r.p.m.
PROCESS CONDITION : Load 7 MW

PEAK NO.	FREQUENCY	ORDER	AMPLITUDE
1	60.0	1.00	13.43
2	240.0	4.00	3.73
3	120.0	2.00	3.35
4	480.0	8.00	2.33
5	180.0	3.00	2.13
6	300.0	5.00	1.86
7	540.0	9.00	1.64
8	420.0	7.00	1.03
9	600.0	10.00	0.61
10	23.7	0.40	0.56

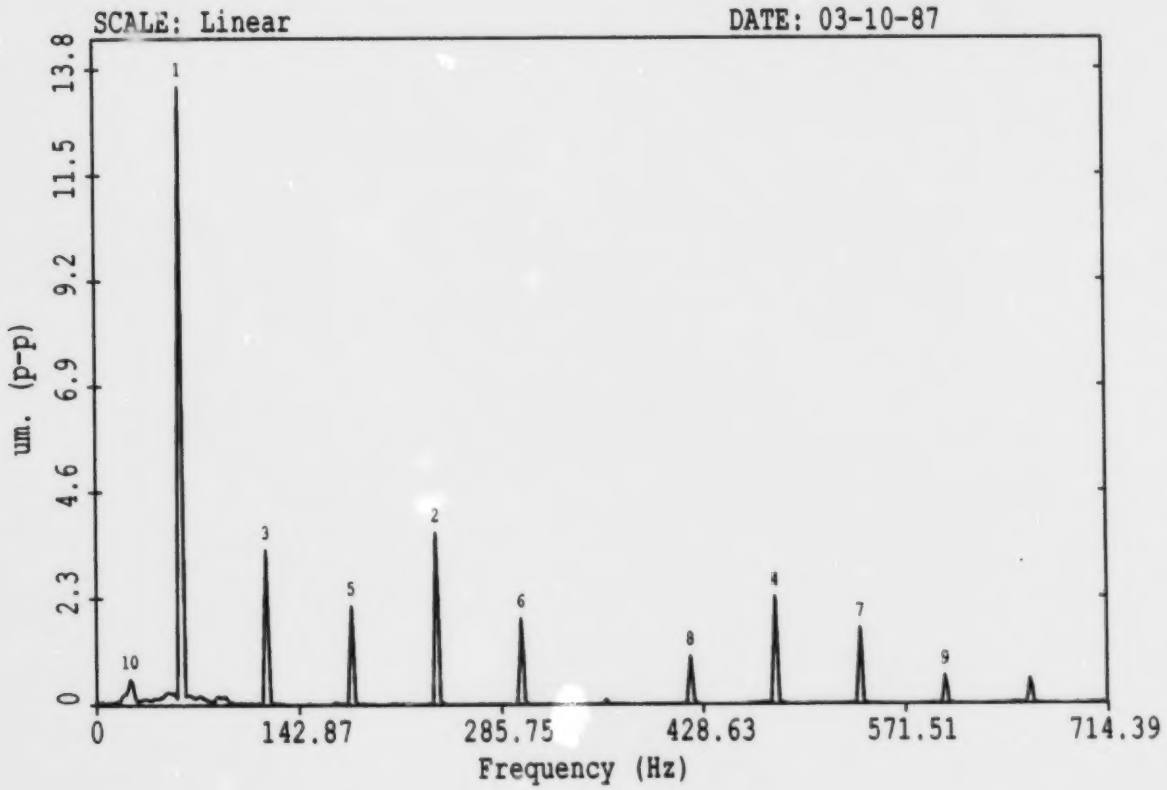

FIGURE 72

Darlington GS Standby Generator #4 AC Generator

SIGNAL : Inboard Brg. Shaft Displacement X-Axis
SPEED : 3600 r.p.m.
PROCESS CONDITION : Load 7 MW

PEAK NO.	FREQUENCY	ORDER	AMPLITUDE
1	60.0	1.00	8.08
2	240.0	4.00	5.70
3	480.0	8.00	4.28
4	180.0	3.00	4.01
5	120.0	2.00	3.72
6	300.0	5.00	3.38
7	420.0	7.00	2.48
8	540.0	9.00	1.99
9	660.0	11.00	1.13
10	600.0	10.00	1.06

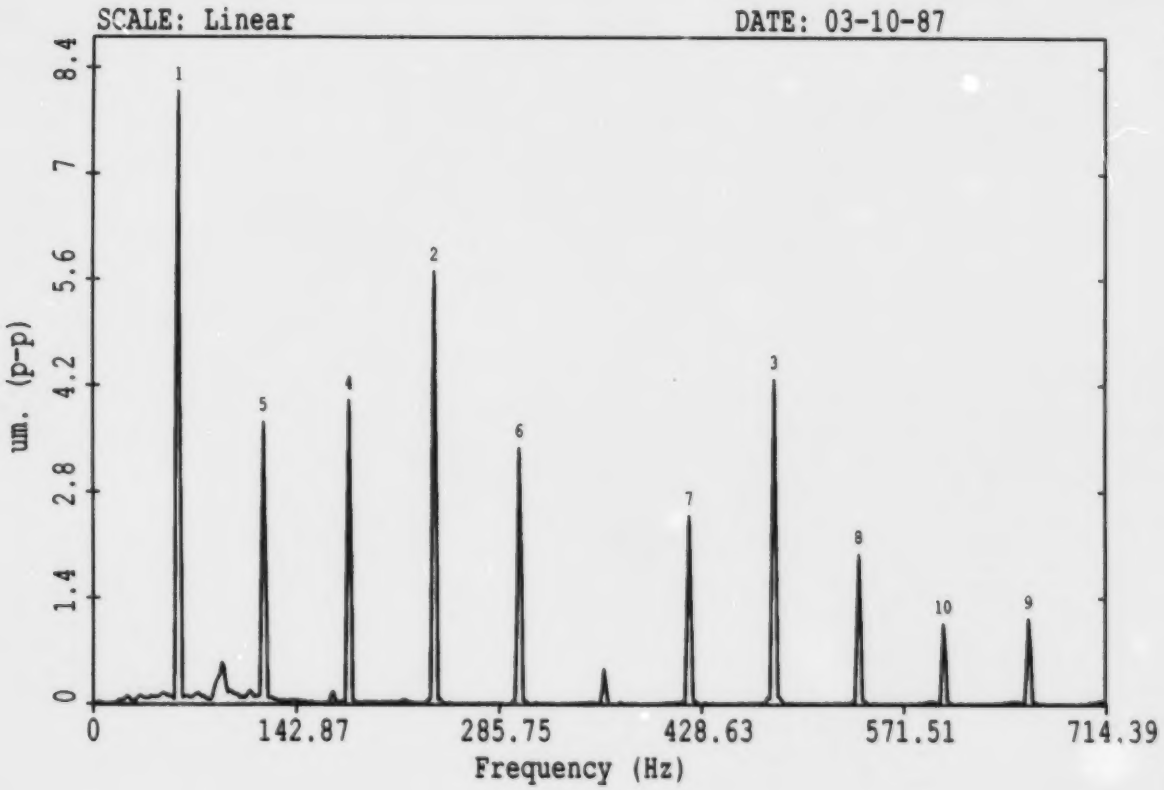

FIGURE 73

Darlington GS Standby Generator #4 AC Generator

SIGNAL : Inboard Brg. Shaft Displacement Y-Axis
SPEED : 3600 r.p.m.
PROCESS CONDITION : Load 7 MW

PEAK NO.	FREQUENCY	ORDER	AMPLITUDE
1	60.0	1.00	7.05
2	240.0	4.00	4.62
3	480.0	8.00	3.11
4	180.0	3.00	3.01
5	300.0	5.00	2.75
6	420.0	7.00	2.03
7	660.0	11.00	1.39
8	120.0	2.00	1.33
9	540.0	9.00	1.16
10	600.0	10.00	1.15

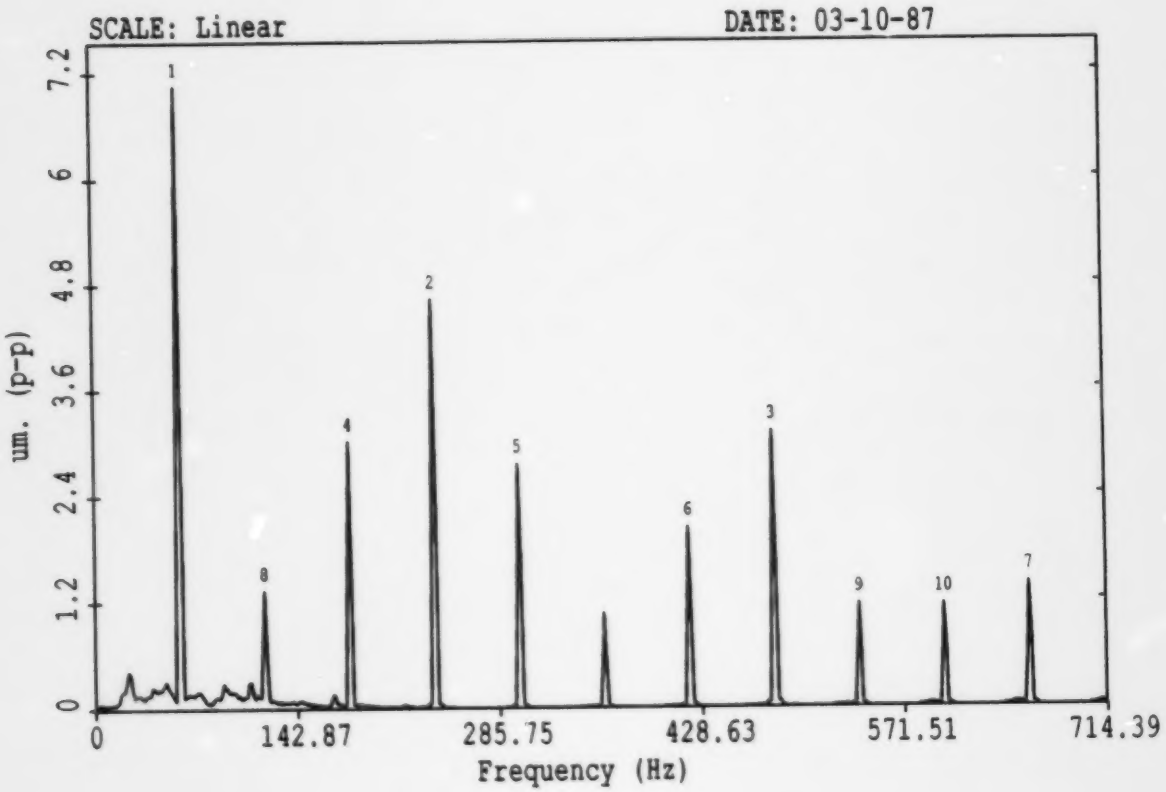

FIGURE 74

Darlington GS Standby Generator #4 AC Generator

SIGNAL : Outboard Brg. Shaft Displacement X-Axis
SPEED : 3600 r.p.m.
PROCESS CONDITION : Load 13 MW

PEAK NO.	FREQUENCY	ORDER	AMPLITUDE
1	60.0	1.00	8.51
2	240.0	4.00	4.31
3	300.0	5.00	2.50
4	120.0	2.00	2.34
5	480.0	8.00	2.24
6	180.0	3.00	1.81
7	540.0	9.00	1.75
8	420.0	7.00	0.98
9	600.0	10.00	0.51
10	660.0	11.00	0.48

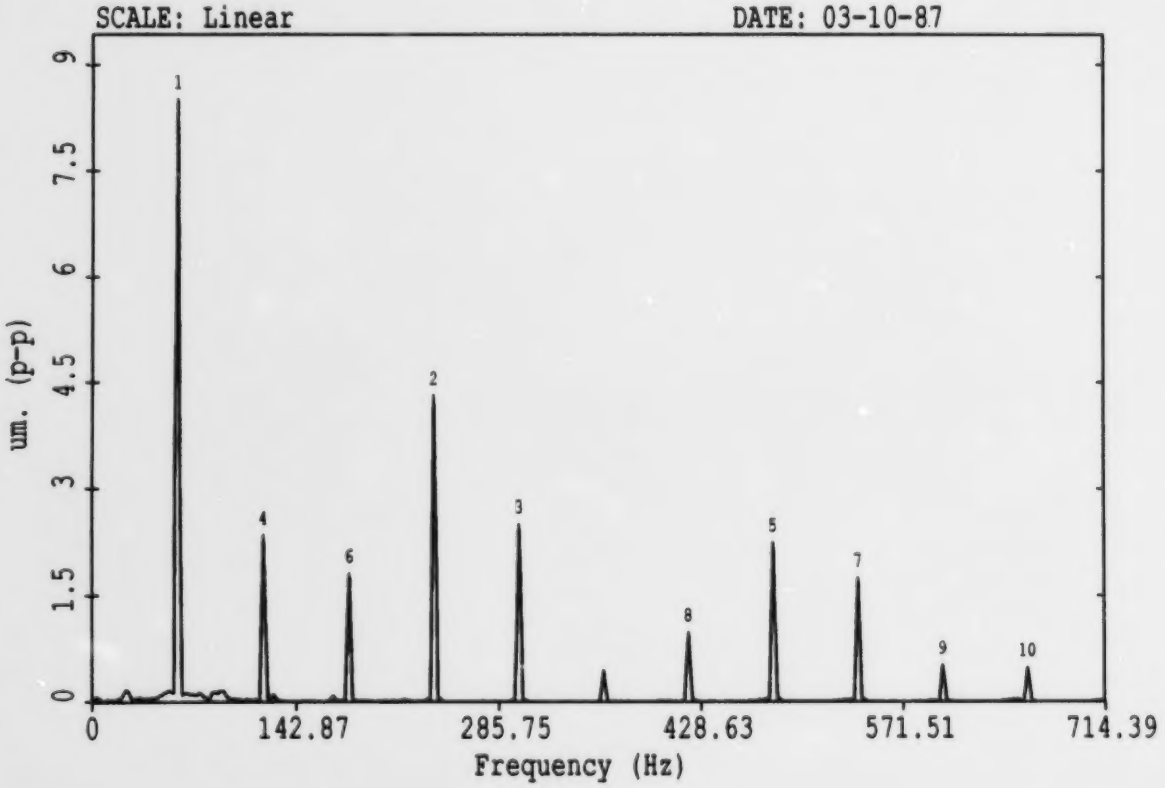

FIGURE 75

Darlington GS Standby Generator #4 AC Generator

SIGNAL : Outboard Brg. Shaft Displacement Y-Axis
SPEED : 3600 r.p.m.
PROCESS CONDITION : Load 13 MW

PEAK NO.	FREQUENCY	ORDER	AMPLITUDE
1	60.0	1.00	12.39
2	240.0	4.00	3.75
3	120.0	2.00	3.11
4	480.0	8.00	2.35
5	180.0	3.00	2.07
6	300.0	5.00	1.84
7	540.0	9.00	1.66
8	420.0	7.00	1.03
9	23.7	0.40	0.65
10	600.0	10.00	0.61

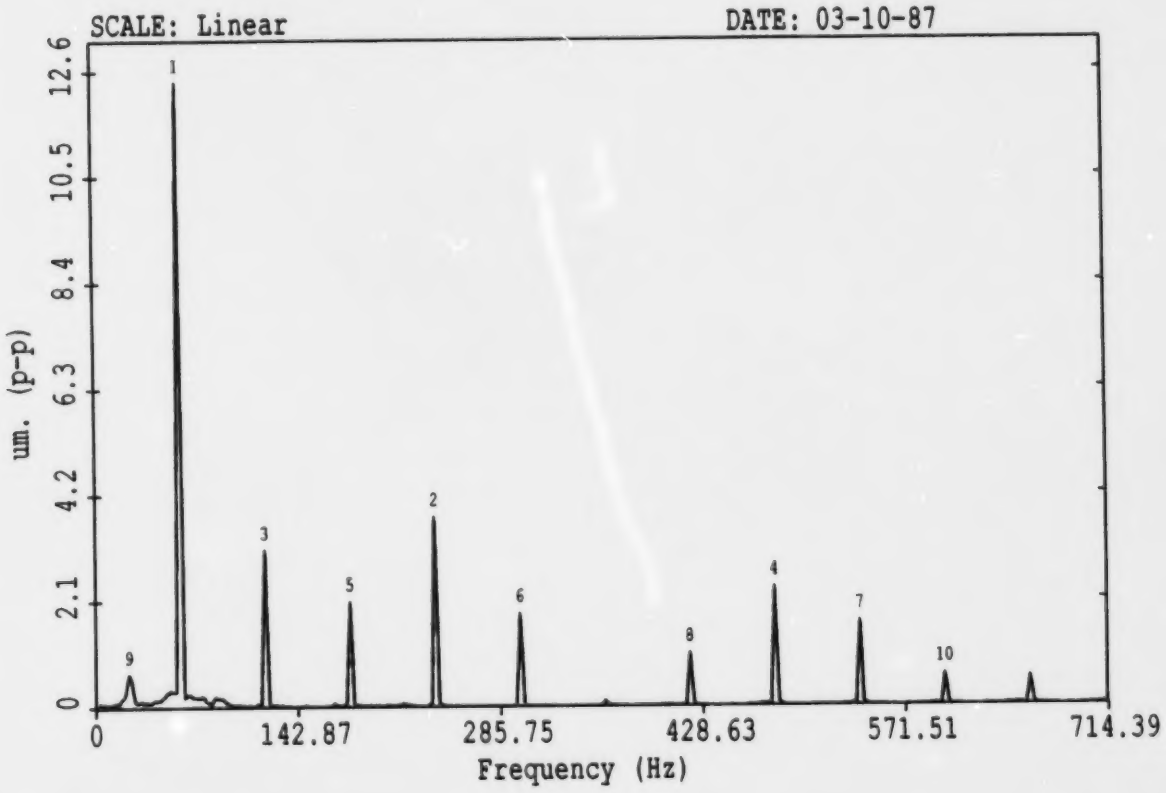

FIGURE 76

Darlington GS Standby Generator #4 AC Generator

SIGNAL : Inboard Brg. Shaft Displacement X-Axis
SPEED : 3600 r.p.m.
PROCESS CONDITION : Load 13 MW

PEAK NO.	FREQUENCY	ORDER	AMPLITUDE
1	60.0	1.00	8.18
2	240.0	4.00	5.74
3	480.0	8.00	4.29
4	180.0	3.00	4.05
5	120.0	2.00	3.98
6	300.0	5.00	3.37
7	420.0	7.00	2.49
8	540.0	9.00	1.98
9	660.0	11.00	1.16
10	600.0	10.00	1.10

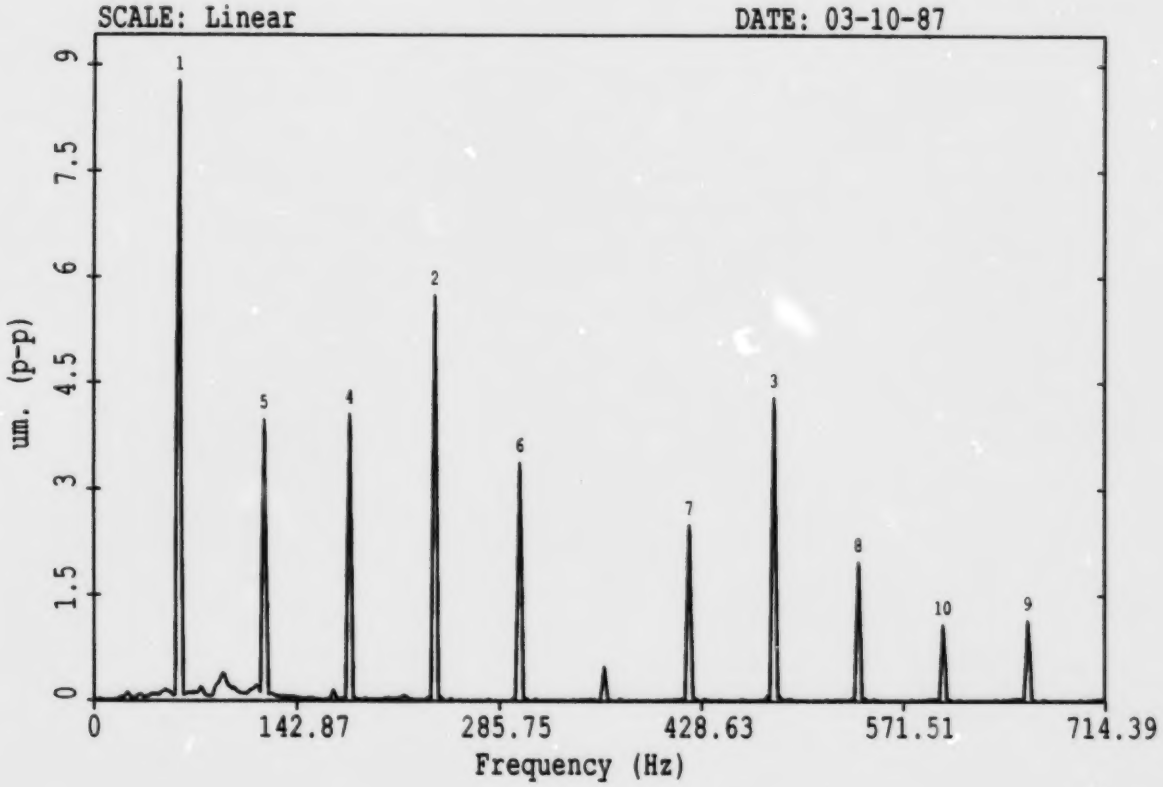

FIGURE 77

Darlington GS Standby Generator #4 AC Generator

SIGNAL : Inboard Brg. Shaft Displacement Y-Axis
SPEED : 3600 r.p.m.
PROCESS CONDITION : Load 13 MW

PEAK NO.	FREQUENCY	ORDER	AMPLITUDE
1	60.0	1.00	7.83
2	240.0	4.00	4.55
3	480.0	8.00	3.08
4	180.0	3.00	2.95
5	300.0	5.00	2.75
6	420.0	7.00	2.01
7	660.0	11.00	1.40
8	600.0	10.00	1.17
9	540.0	9.00	1.14
10	360.0	6.00	1.09

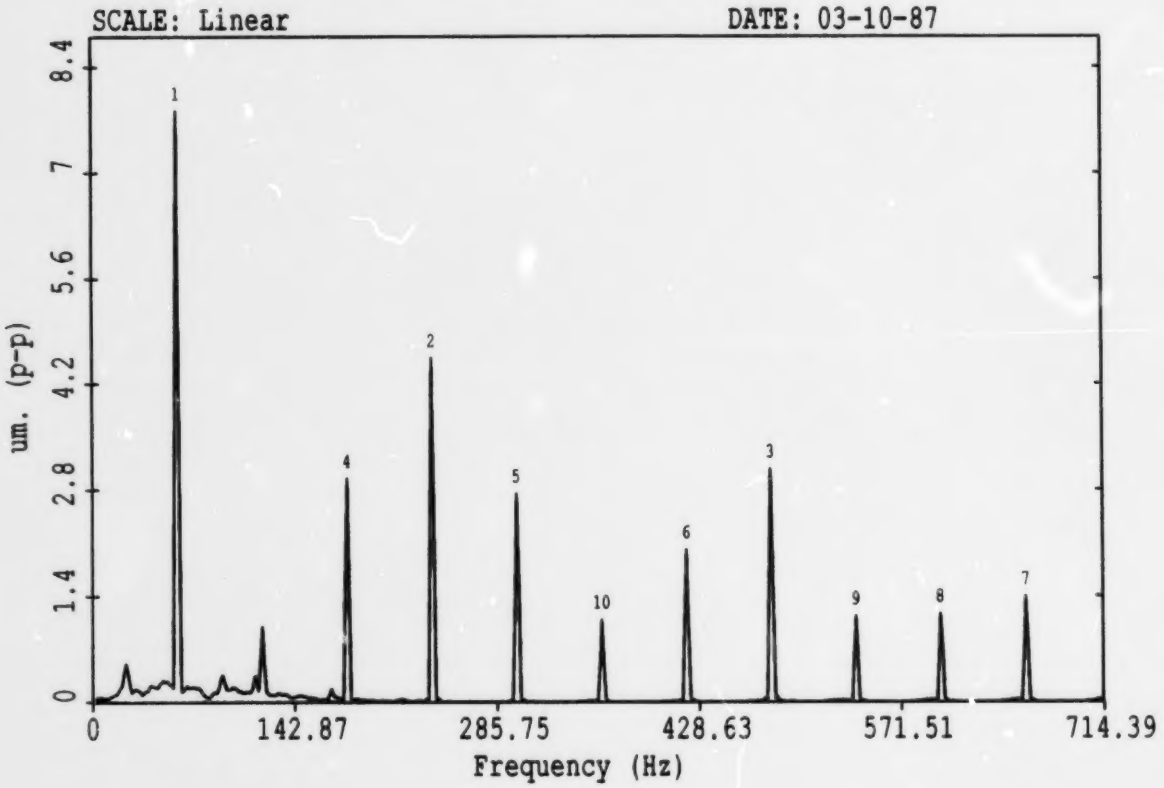

FIGURE 78

Darlington GS Standby Generator #4 AC Generator

SIGNAL : Outboard Brg. Shaft Displacement X-Axis
SPEED : 3600 r.p.m.
PROCESS CONDITION : Load 20 MW

PEAK NO.	FREQUENCY	ORDER	AMPLITUDE
1	60.0	1.00	8.16
2	240.0	4.00	4.32
3	300.0	5.00	2.49
4	120.0	2.00	2.45
5	480.0	8.00	2.24
6	180.0	3.00	1.87
7	540.0	9.00	1.74
8	420.0	7.00	0.99
9	600.0	10.00	0.52
10	660.0	11.00	0.49

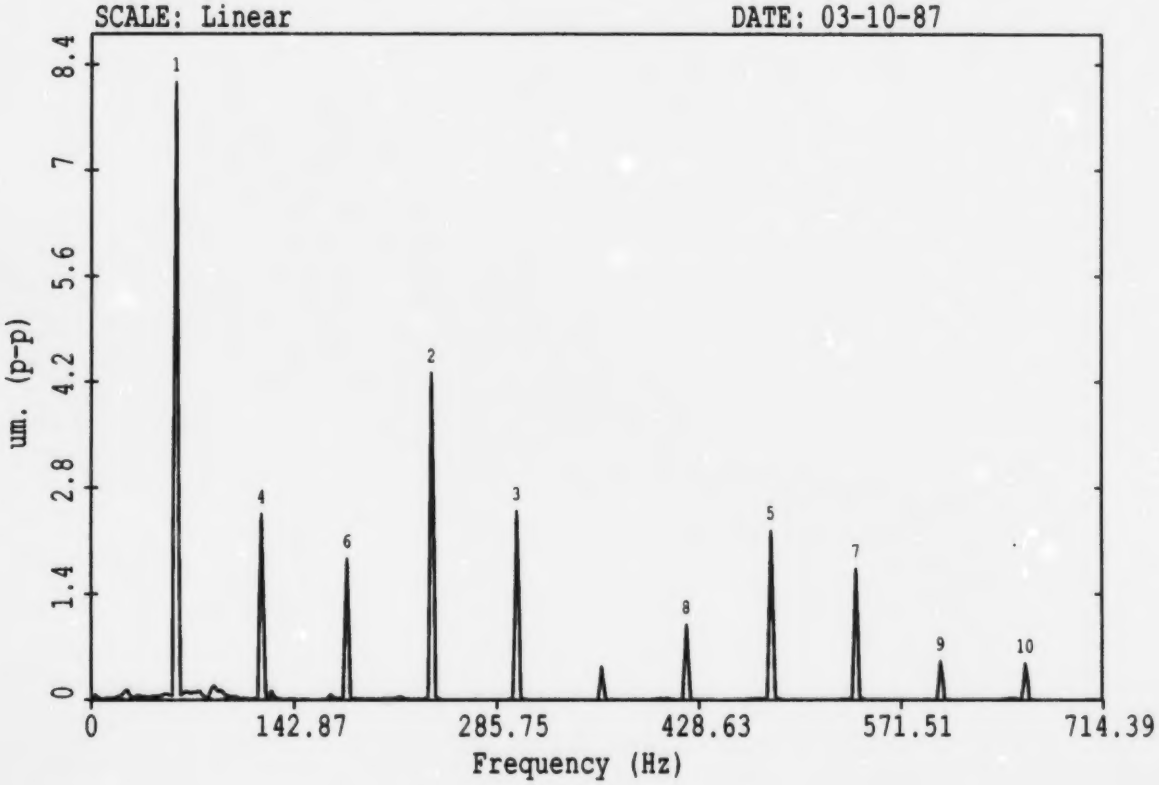

FIGURE 79

Darlington GS Standby Generator #4 AC Generator

SIGNAL : Outboard Brg. Shaft Displacement Y-Axis
SPEED : 3600 r.p.m.
PROCESS CONDITION : Load 20 MW

PEAK NO.	FREQUENCY	ORDER	AMPLITUDE
1	60.0	1.00	11.11
2	240.0	4.00	3.67
3	120.0	2.00	3.10
4	480.0	8.00	2.35
5	180.0	3.00	2.00
6	300.0	5.00	1.81
7	540.0	9.00	1.66
8	420.0	7.00	1.03
9	600.0	10.00	0.61
10	660.0	11.00	0.55

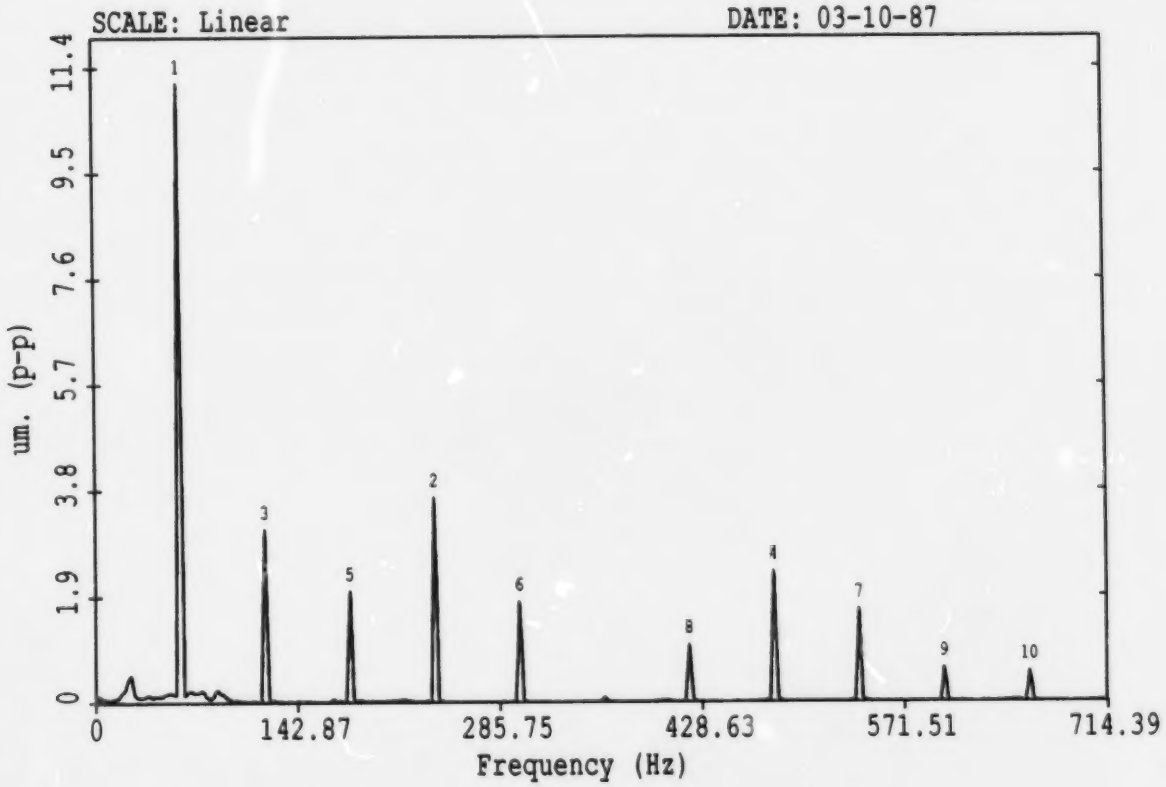

FIGURE 80

Darlington GS Standby Generator #4 AC Generator

SIGNAL : Inboard Brg. Shaft Displacement X-Axis
SPEED : 3600 r.p.m.
PROCESS CONDITION : Load 20 MW

PEAK NO.	FREQUENCY	ORDER	AMPLITUDE
1	60.0	1.00	9.47
2	240.0	4.00	5.74
3	480.0	8.00	4.27
4	180.0	3.00	4.06
5	120.0	2.00	3.98
6	300.0	5.00	3.38
7	420.0	7.00	2.48
8	540.0	9.00	1.98
9	660.0	11.00	1.18
10	600.0	10.00	1.09

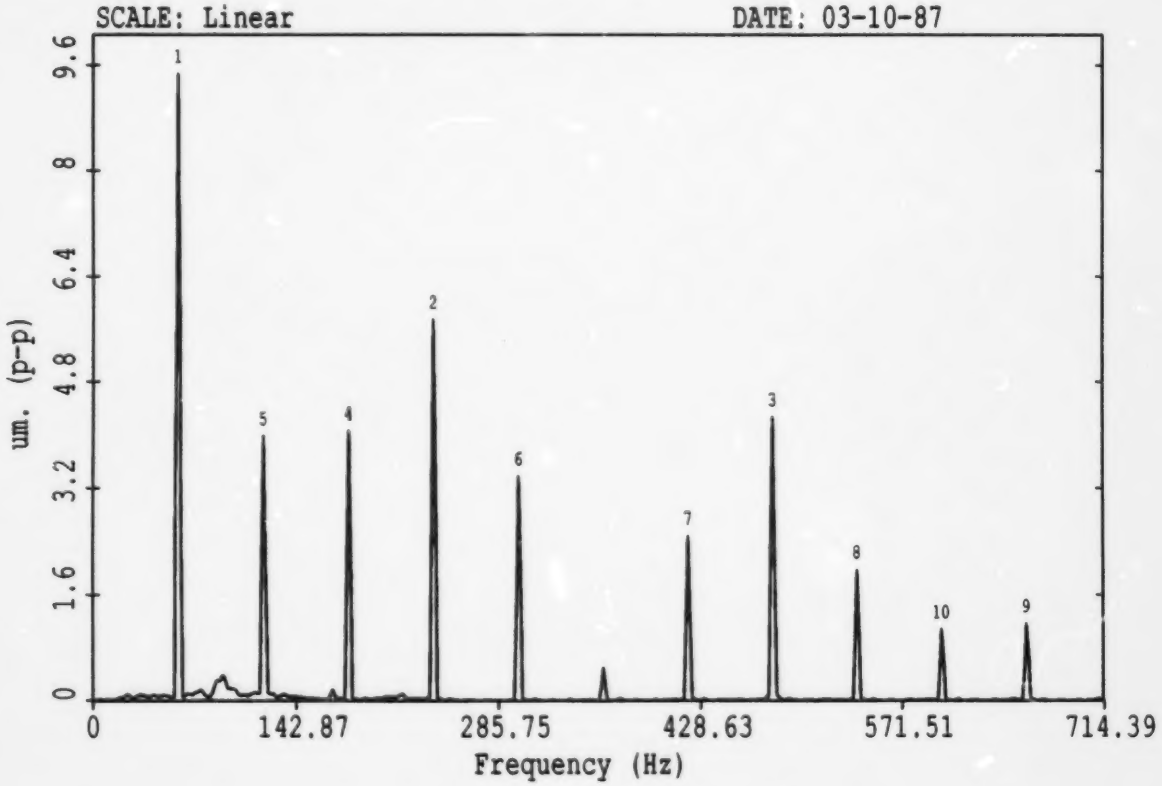

FIGURE 81

Darlington GS Standby Generator #4 AC Generator

SIGNAL : Inboard Brg. Shaft Displacement Y-Axis
SPEED : 3600 r.p.m.
PROCESS CONDITION : Load 20 MW

PEAK NO.	FREQUENCY	ORDER	AMPLITUDE
1	60.0	1.00	8.36
2	240.0	4.00	4.46
3	480.0	8.00	3.01
4	180.0	3.00	2.94
5	300.0	5.00	2.72
6	420.0	7.00	1.99
7	660.0	11.00	1.38
8	600.0	10.00	1.16
9	540.0	9.00	1.12
10	360.0	6.00	1.09

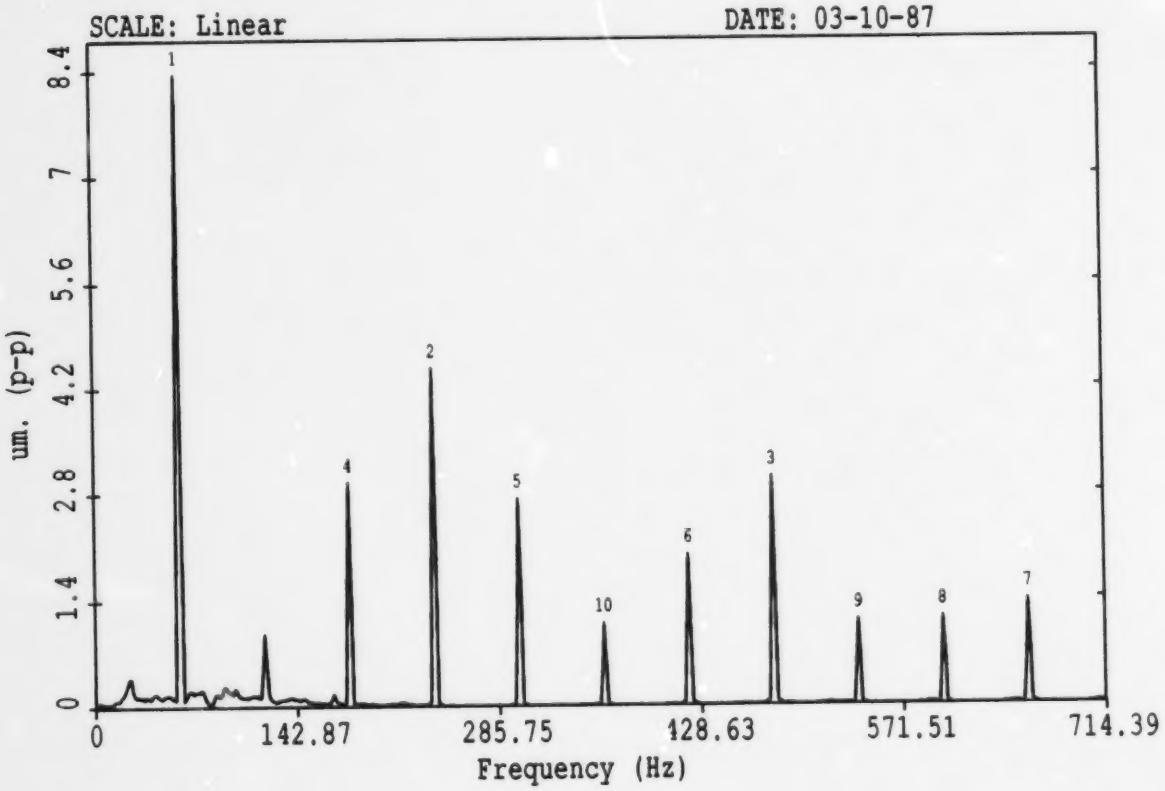

FIGURE 82

Darlington GS Standby Generator #4 AC Generator

SIGNAL : Outboard Brg. Shaft Displacement X-Axis
SPEED : 3600 r.p.m.
PROCESS CONDITION : Load 26 MW

PEAK NO.	FREQUENCY	ORDER	AMPLITUDE
1	60.0	1.00	8.00
2	240.0	4.00	4.35
3	300.0	5.00	2.50
4	120.0	2.00	2.49
5	480.0	8.00	2.25
6	180.0	3.00	1.91
7	540.0	9.00	1.75
8	420.0	7.00	1.01
9	600.0	10.00	0.52
10	660.0	11.00	0.49

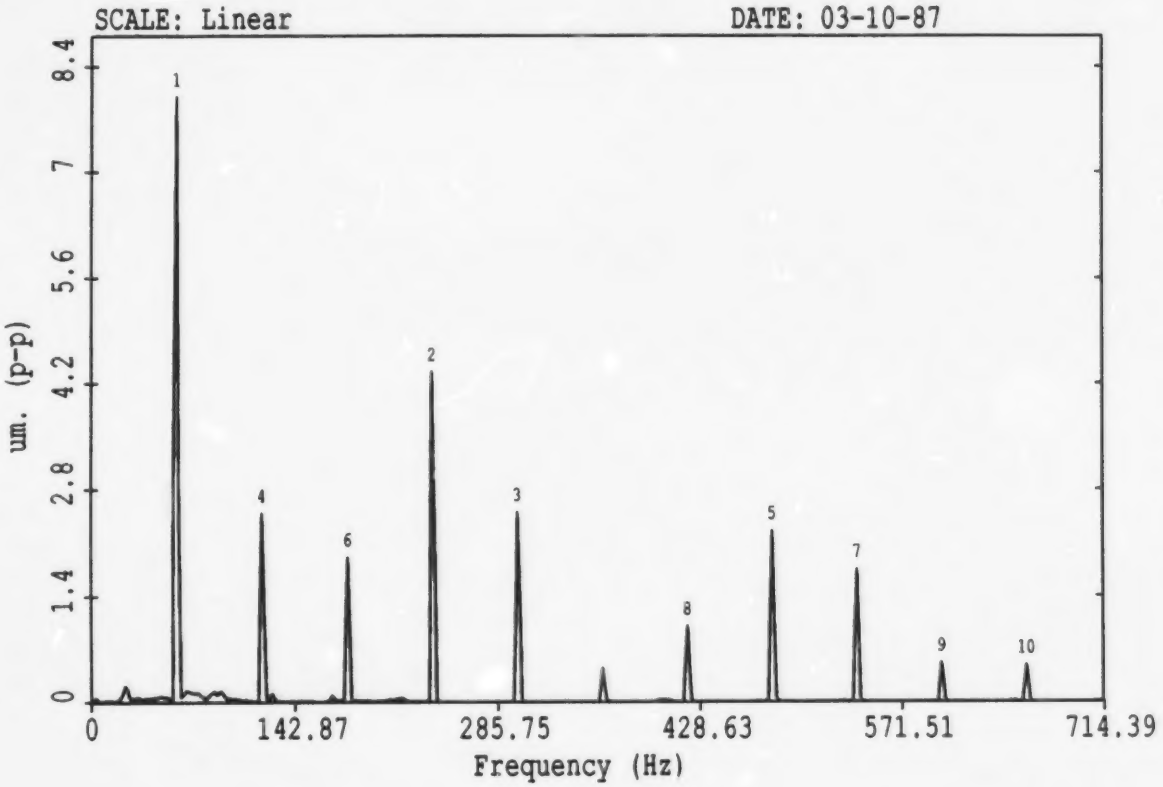

FIGURE 83

Darlington GS Standby Generator #4 AC Generator

SIGNAL : Outboard Brg. Shaft Displacement Y-Axis
SPEED : 3600 r.p.m.
PROCESS CONDITION : Load 26 MW

PEAK NO.	FREQUENCY	ORDER	AMPLITUDE
1	60.0	1.00	10.38
2	240.0	4.00	3.68
3	120.0	2.00	3.06
4	480.0	8.00	2.36
5	180.0	3.00	2.02
6	300.0	5.00	1.80
7	540.0	9.00	1.67
8	420.0	7.00	1.03
9	23.7	0.40	0.85
10	600.0	10.00	0.62

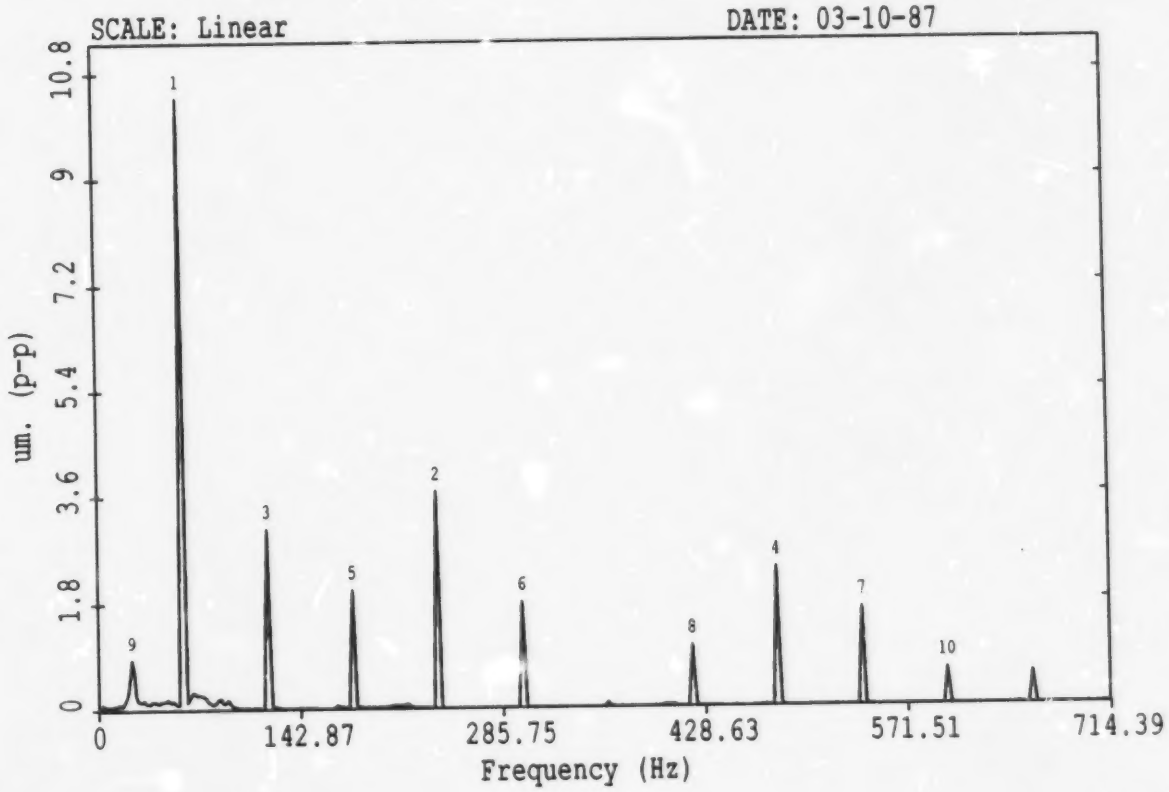

FIGURE 84

Darlington GS Standby Generator #4 AC Generator

SIGNAL : Inboard Brg. Shaft Displacement X-Axis
SPEED : 3600 r.p.m.
PROCESS CONDITION : Load 26 MW

PEAK NO.	FREQUENCY	ORDER	AMPLITUDE
1	60.0	1.00	9.62
2	240.0	4.00	5.76
3	480.0	8.00	4.28
4	180.0	3.00	4.05
5	120.0	2.00	3.70
6	300.0	5.00	3.37
7	420.0	7.00	2.48
8	540.0	9.00	1.99
9	660.0	11.00	1.19
10	600.0	10.00	1.10

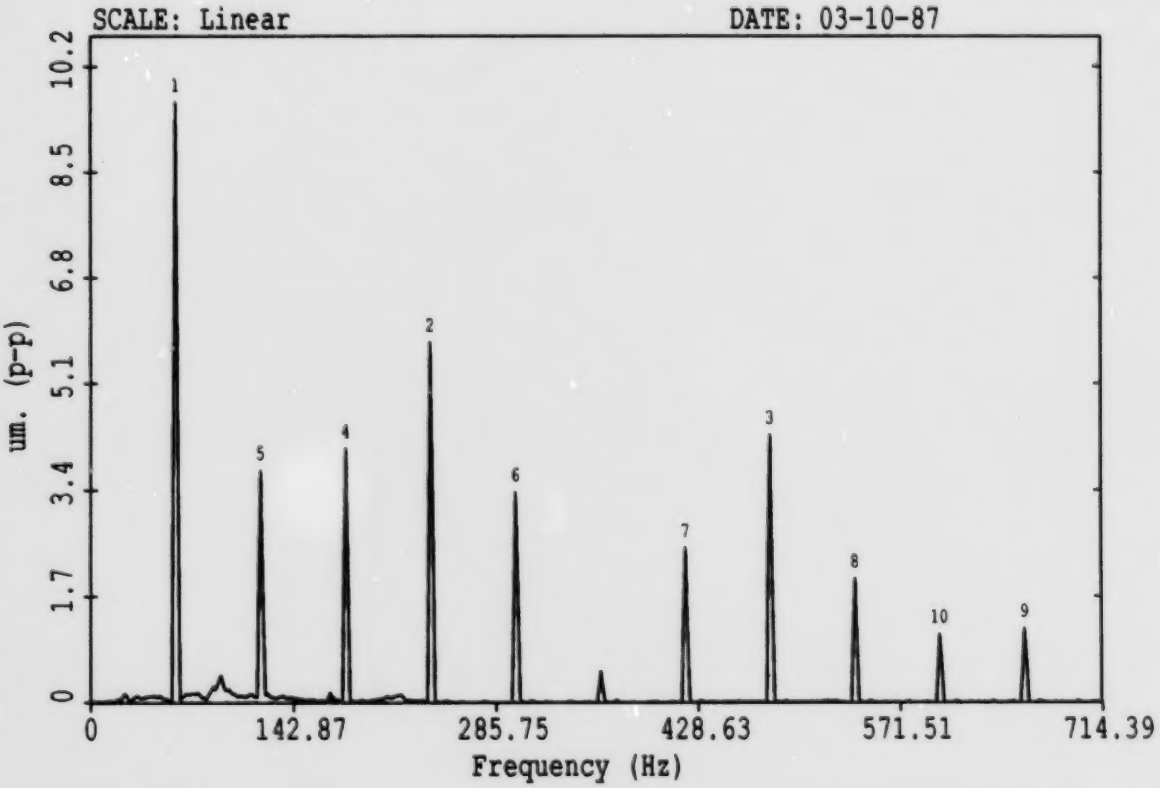

FIGURE 85

Darlington GS Standby Generator #4 AC Generator

SIGNAL : Inboard Brg. Shaft Displacement Y-Axis
SPEED : 3600 r.p.m.
PROCESS CONDITION : Load 26 MW

PEAK NO.	FREQUENCY	ORDER	AMPLITUDE
1	60.0	1.00	7.89
2	240.0	4.00	4.40
3	180.0	3.00	3.02
4	480.0	8.00	3.02
5	300.0	5.00	2.71
6	420.0	7.00	1.99
7	660.0	11.00	1.39
8	600.0	10.00	1.17
9	540.0	9.00	1.12
10	360.0	6.00	1.09

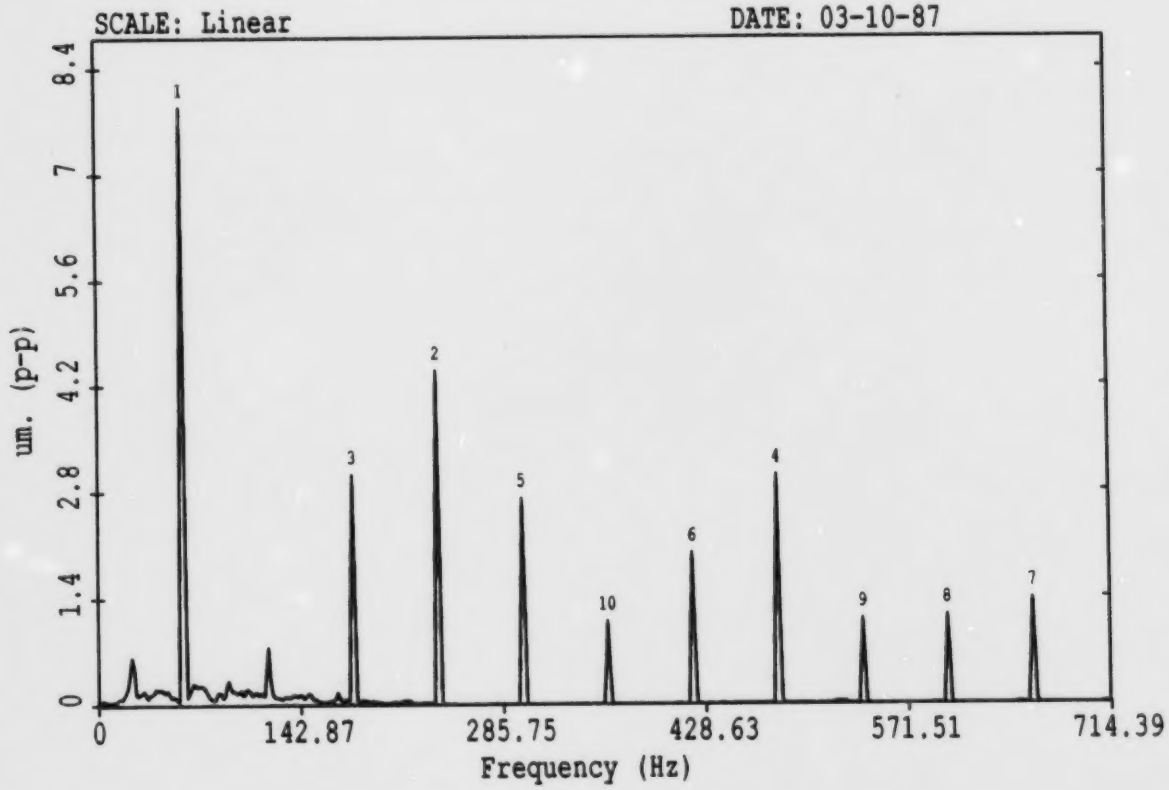

FIGURE 86

Darlington GS Standby Generator #4 Power Turbine

SIGNAL : Inboard Brg. Shaft Displacement X-Axis
SPEED : 3600 r.p.m.
PROCESS CONDITION : Load 0 MW

PEAK NO.	FREQUENCY	ORDER	AMPLITUDE
1	60.0	1.00	32.24
2	120.0	2.00	4.70
3	32.1	0.53	4.30
4	40.5	0.67	4.24
5	15.3	0.26	3.45
6	48.8	0.81	3.19
7	180.0	3.00	3.07
8	44.6	0.74	2.54
9	240.0	4.00	1.58
10	8.4	0.14	1.04

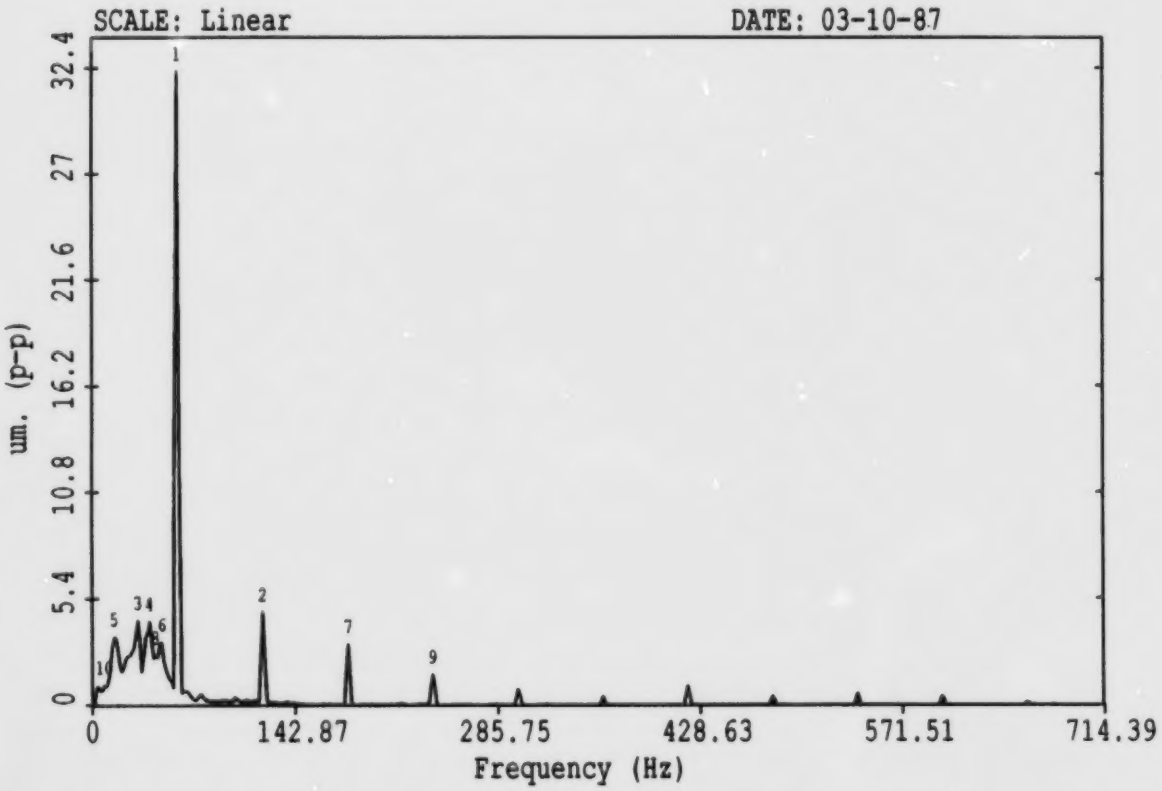

FIGURE 87

Darlington GS Standby Generator #4 Power Turbine

SIGNAL : Inboard Brg. Shaft Displacement Y-Axis
SPEED : 3600 r.p.m.
PROCESS CONDITION : Load 0 MW

PEAK NO.	FREQUENCY	ORDER	AMPLITUDE
1	60.0	1.00	43.82
2	32.1	0.53	8.64
3	16.7	0.28	8.33
4	40.5	0.67	6.65
5	37.7	0.63	6.38
6	120.0	2.00	5.97
7	44.6	0.74	4.25
8	180.0	3.00	2.80
9	9.8	0.16	2.23
10	4.2	0.07	1.96

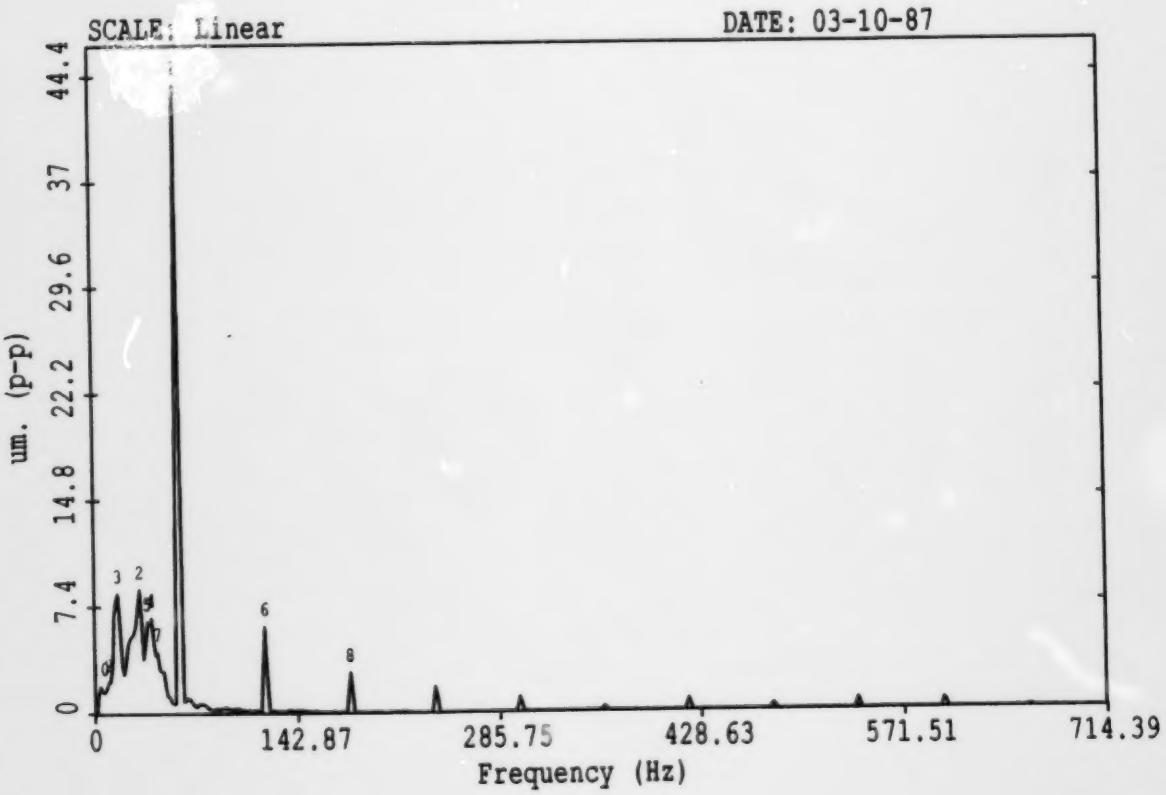

FIGURE 88

Darlington GS Standby Generator #4 Power Turbine

SIGNAL : Outboard Brg. Shaft Displacement X-Axis
SPEED : 3600 r.p.m.
PROCESS CONDITION : Load 0 MW

PEAK NO.	FREQUENCY	ORDER	AMPLITUDE
1	60.0	1.00	8.52
2	19.5	0.33	4.36
3	120.0	2.00	3.68
4	300.0	5.00	1.99
5	240.0	4.00	1.63
6	420.0	7.00	1.58
7	180.0	3.00	1.53
8	32.1	0.53	1.37
9	37.7	0.63	1.31
10	660.0	11.00	1.21

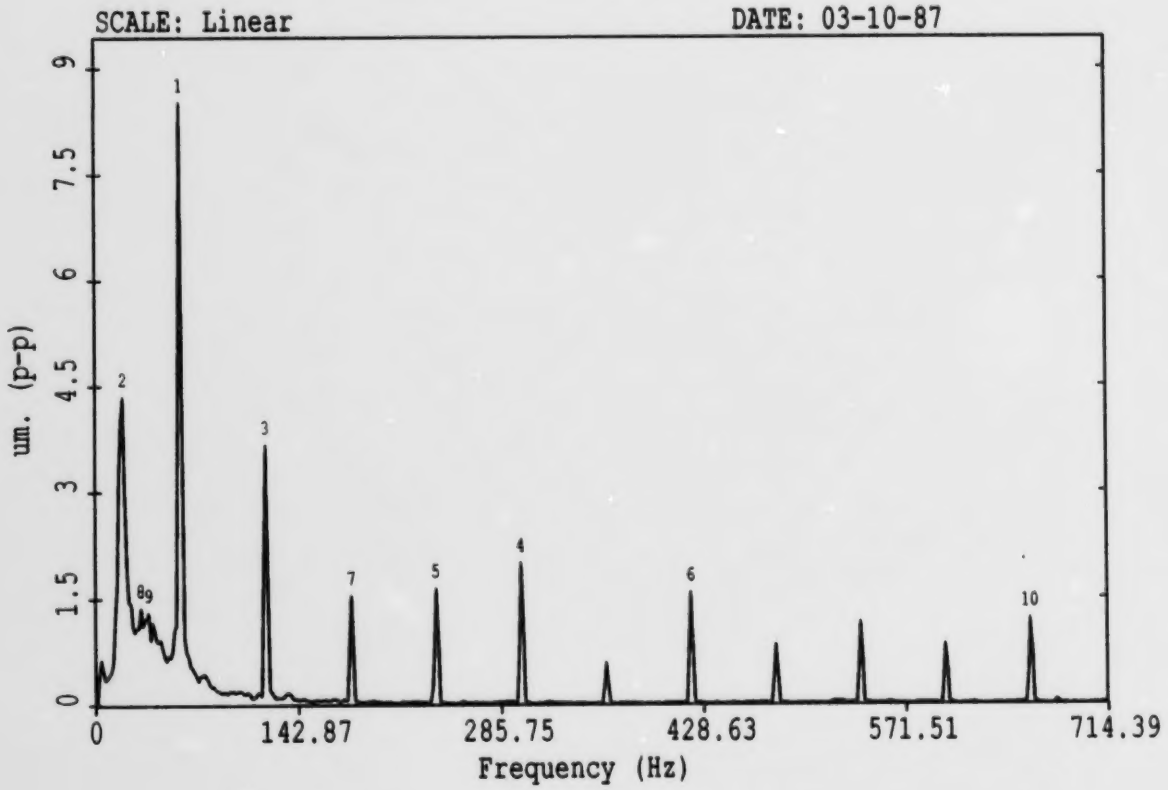

FIGURE 89

Darlington GS Standby Generator #4 Power Turbine

SIGNAL : Outboard Brg. Shaft Displacement Y-Axis
SPEED : 3600 r.p.m.
PROCESS CONDITION : Load 0 MW

PEAK NO.	FREQUENCY	ORDER	AMPLITUDE
1	60.0	1.00	41.49
2	19.5	0.33	12.06
3	120.0	2.00	4.45
4	32.1	0.53	3.96
5	55.8	0.93	3.24
6	180.0	3.00	2.77
7	240.0	4.00	2.44
8	47.4	0.79	2.26
9	300.0	5.00	2.23
10	51.6	0.86	2.10

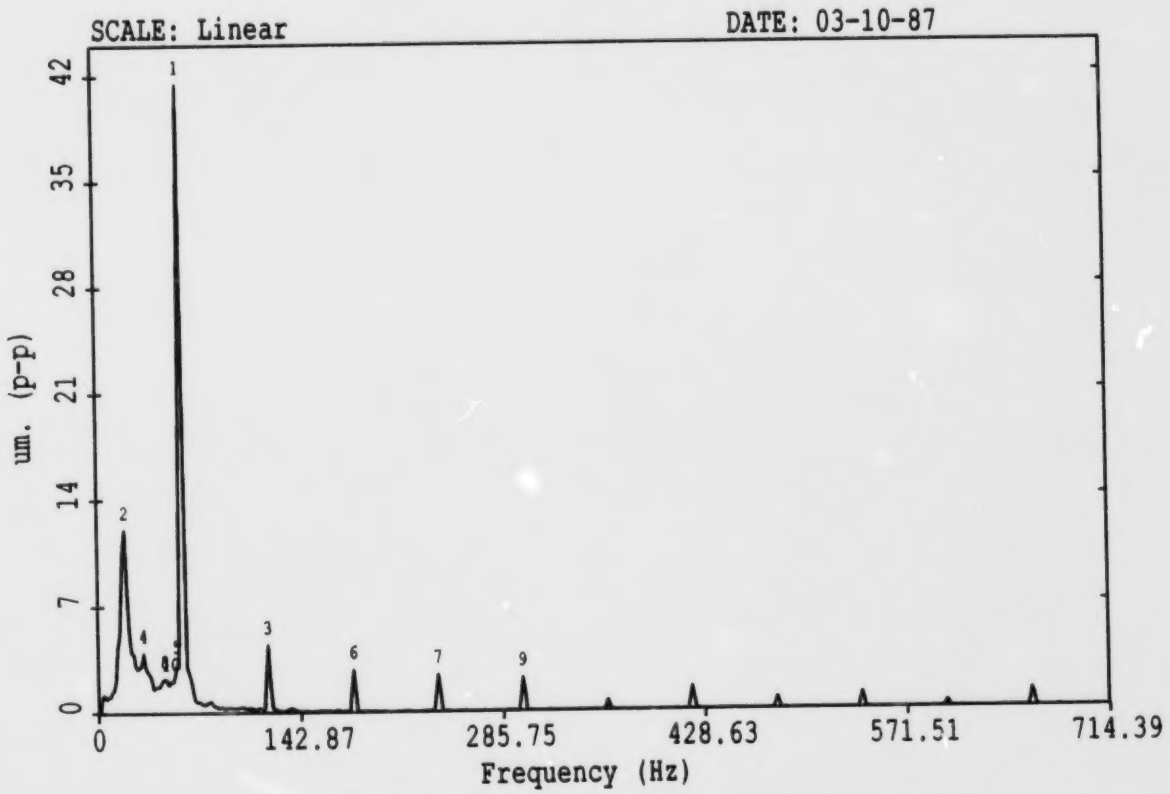

FIGURE 90

Darlington GS Standby Generator #4 Power Turbine

SIGNAL : Inboard Brg. Shaft Displacement X-Axis
SPEED : 3600 r.p.m.
PROCESS CONDITION : Load 7 MW

PEAK NO.	FREQUENCY	ORDER	AMPLITUDE
1	60.0	1.00	40.81
2	120.0	2.00	4.80
3	32.1	0.53	4.08
4	15.3	0.26	3.30
5	180.0	3.00	2.85
6	40.5	0.67	2.40
7	50.2	0.84	2.32
8	37.7	0.63	2.13
9	46.0	0.77	1.94
10	240.0	4.00	1.77

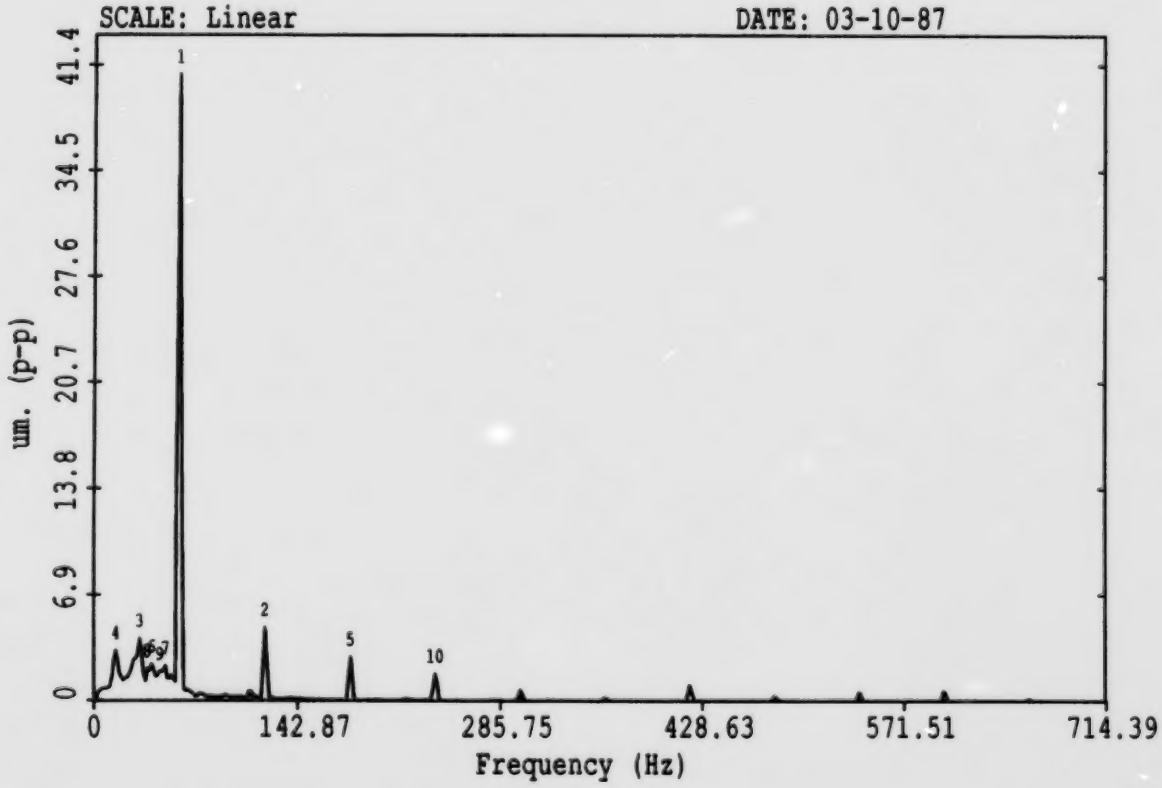

FIGURE 91

Darlington GS Standby Generator #4 Power Turbine

SIGNAL : Inboard Brg. Shaft Displacement Y-Axis
SPEED : 3600 r.p.m.
PROCESS CONDITION : Load 7 MW

PEAK NO.	FREQUENCY	ORDER	AMPLITUDE
1	60.0	1.00	50.80
2	32.1	0.53	7.38
3	120.0	2.00	6.52
4	15.3	0.26	6.49
5	40.5	0.67	3.62
6	37.7	0.63	3.54
7	180.0	3.00	3.19
8	22.3	0.37	2.64
9	44.6	0.74	2.56
10	50.2	0.84	2.23

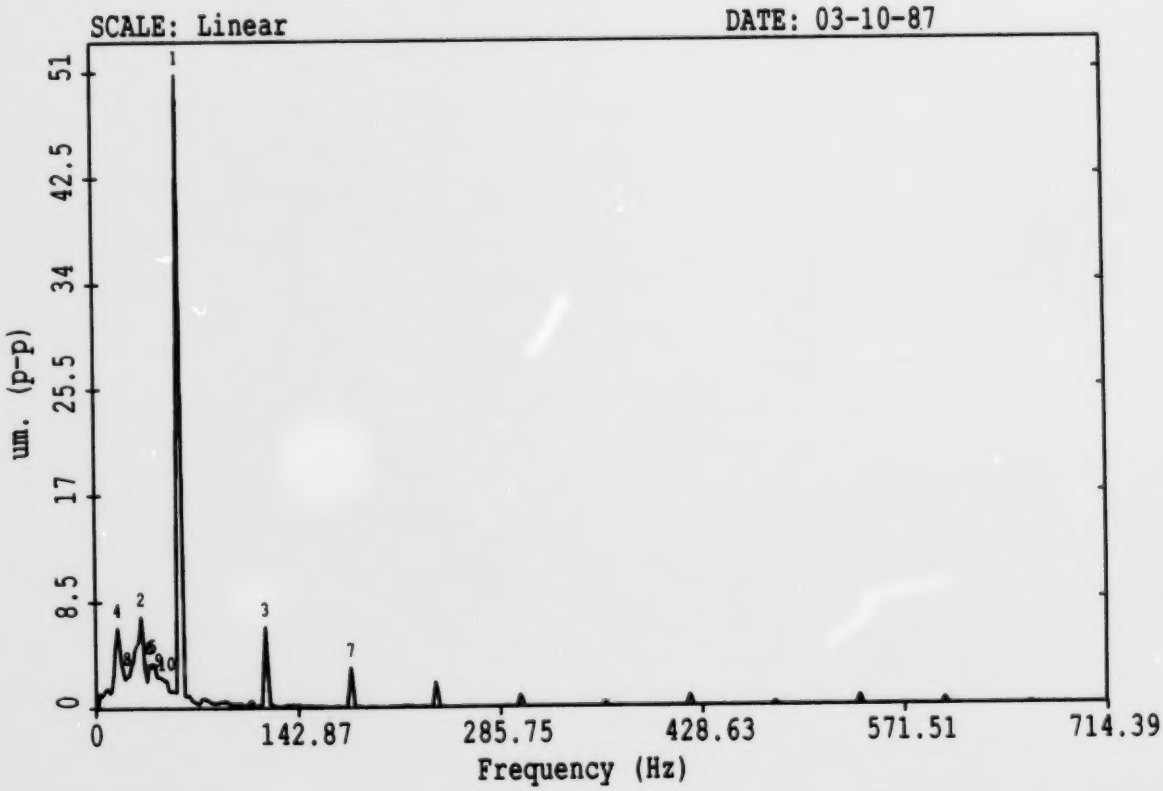

FIGURE 92

Darlington GS Standby Generator #4 Power Turbine

SIGNAL : Outboard Brg. Shaft Displacement X-Axis
SPEED : 3600 r.p.m.
PROCESS CONDITION : Load 7 MW

PEAK NO.	FREQUENCY	ORDER	AMPLITUDE
1	60.0	1.00	8.13
2	19.5	0.33	4.84
3	120.0	2.00	3.41
4	300.0	5.00	1.78
5	240.0	4.00	1.60
6	180.0	3.00	1.49
7	420.0	7.00	1.49
8	32.1	0.53	1.25
9	540.0	9.00	1.14
10	40.5	0.67	1.13

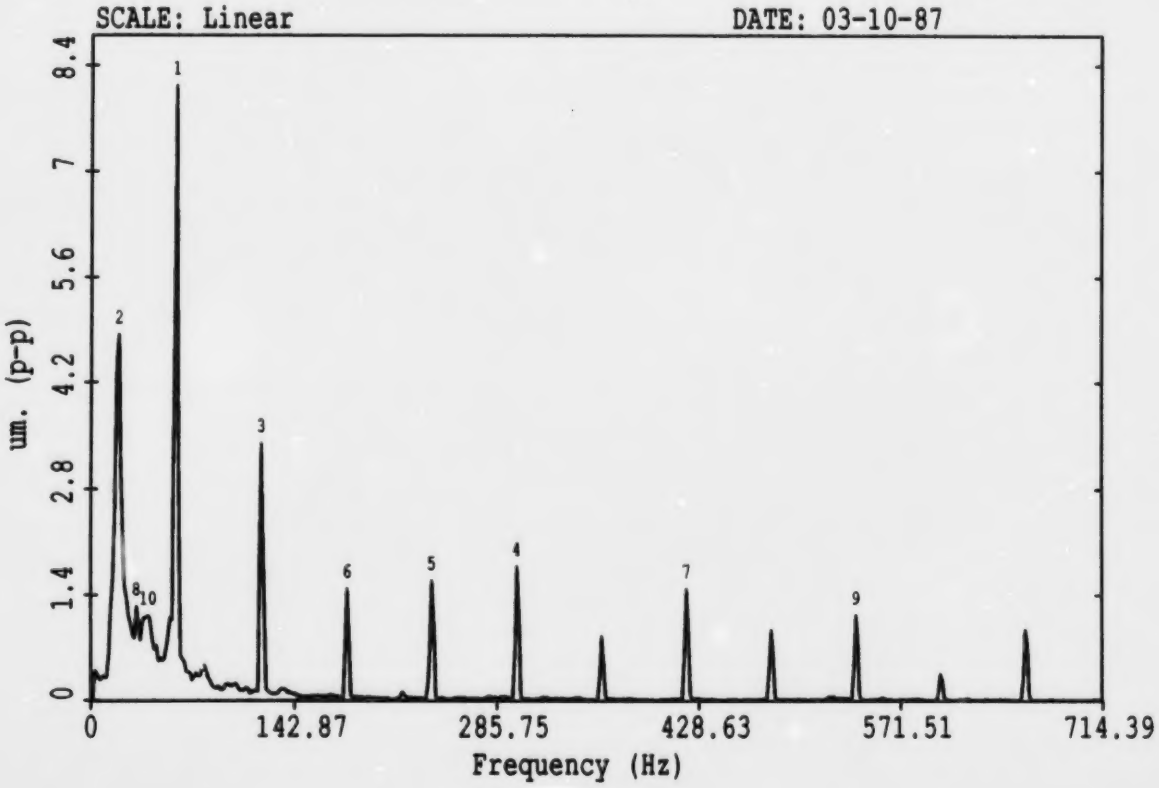

FIGURE 93

Darlington GS Standby Generator #4 Power Turbine

SIGNAL : Outboard Brg. Shaft Displacement Y-Axis
SPEED : 3600 r.p.m.
PROCESS CONDITION : Load 7 MW

PEAK NO.	FREQUENCY	ORDER	AMPLITUDE
1	60.0	1.00	33.21
2	19.5	0.33	14.15
3	120.0	2.00	4.78
4	32.1	0.53	3.40
5	55.8	0.93	3.01
6	180.0	3.00	2.81
7	37.7	0.63	2.60
8	46.0	0.77	2.10
9	240.0	4.00	2.02
10	300.0	5.00	1.93

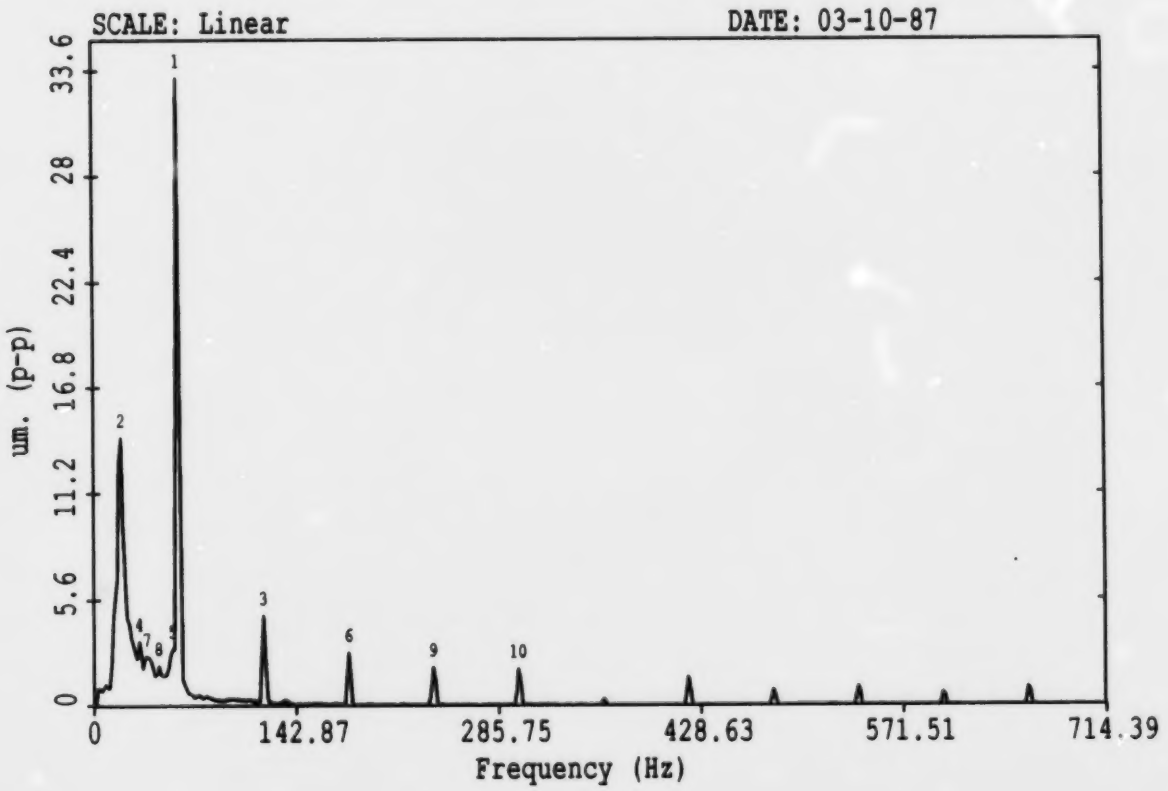

FIGURE 94

Darlington GS Standby Generator #4 Power Turbine

SIGNAL : Inboard Brg. Shaft Displacement X-Axis
SPEED : 3600 r.p.m.
PROCESS CONDITION : Load 13 MW

PEAK NO.	FREQUENCY	ORDER	AMPLITUDE
1	60.0	1.00	40.46
2	120.0	2.00	5.38
3	32.1	0.53	3.42
4	53.0	0.88	3.39
5	180.0	3.00	2.96
6	15.3	0.26	2.68
7	40.5	0.67	2.44
8	240.0	4.00	1.78
9	46.0	0.77	1.36
10	420.0	7.00	1.00

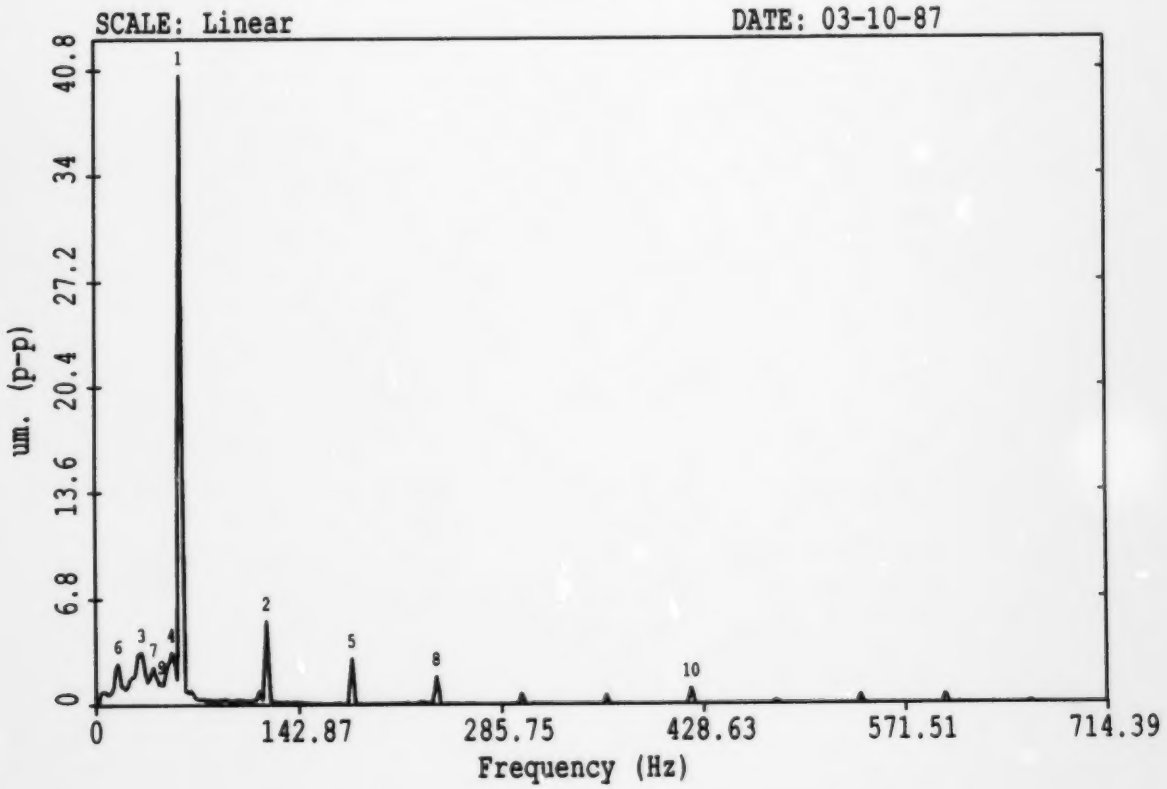

FIGURE 95

Darlington GS Standby Generator #4 Power Turbine

SIGNAL : Inboard Brg. Shaft Displacement Y-Axis
SPEED : 3600 r.p.m.
PROCESS CONDITION : Load 13 MW

PEAK NO.	FREQUENCY	ORDER	AMPLITUDE
1	60.0	1.00	50.97
2	120.0	2.00	6.61
3	32.1	0.53	6.32
4	15.3	0.26	4.97
5	40.5	0.67	3.73
6	53.0	0.88	3.26
7	180.0	3.00	3.12
8	50.2	0.84	2.80
9	240.0	4.00	2.04
10	46.0	0.77	2.01

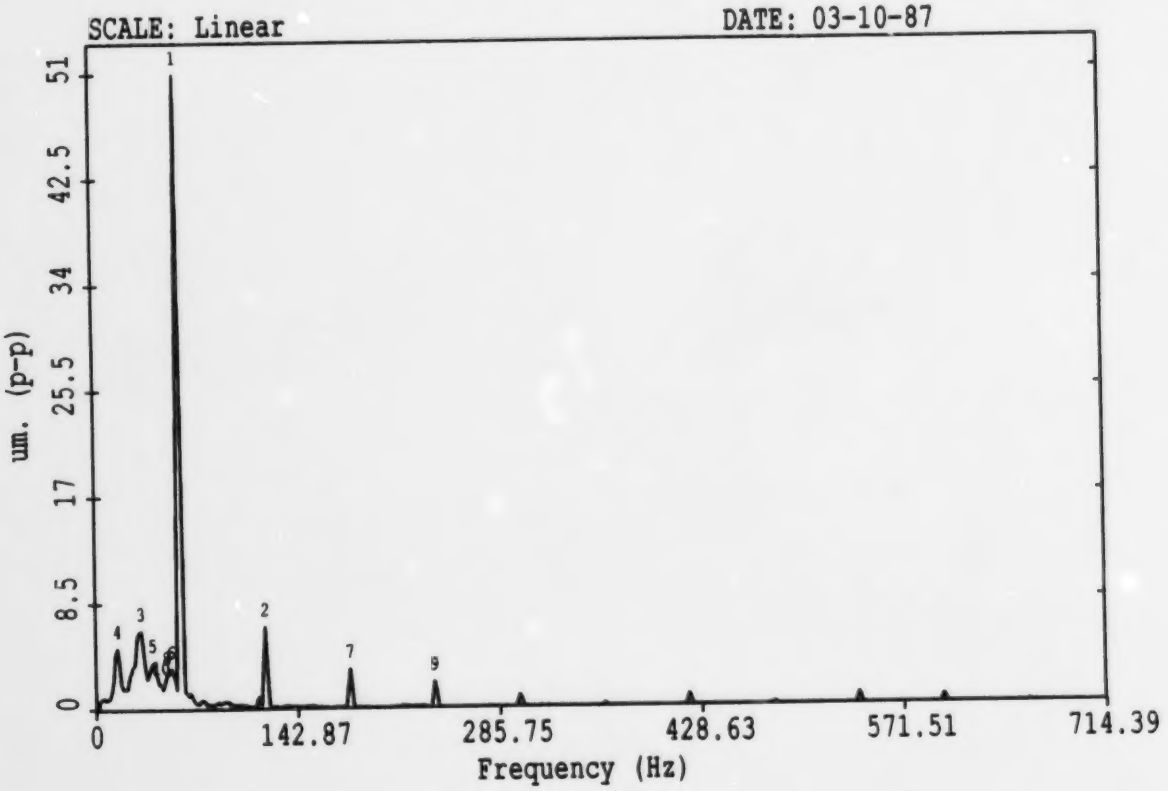

FIGURE 96

Darlington GS Standby Generator #4 Power Turbine

SIGNAL : Outboard Brg. Shaft Displacement X-Axis
SPEED : 3600 r.p.m.
PROCESS CONDITION : Load 13 MW

PEAK NO.	FREQUENCY	ORDER	AMPLITUDE
1	60.0	1.00	7.66
2	19.5	0.33	3.74
3	120.0	2.00	3.36
4	300.0	5.00	1.75
5	420.0	7.00	1.53
6	36.3	0.60	1.48
7	180.0	3.00	1.47
8	240.0	4.00	1.33
9	540.0	9.00	1.16
10	55.8	0.93	1.14

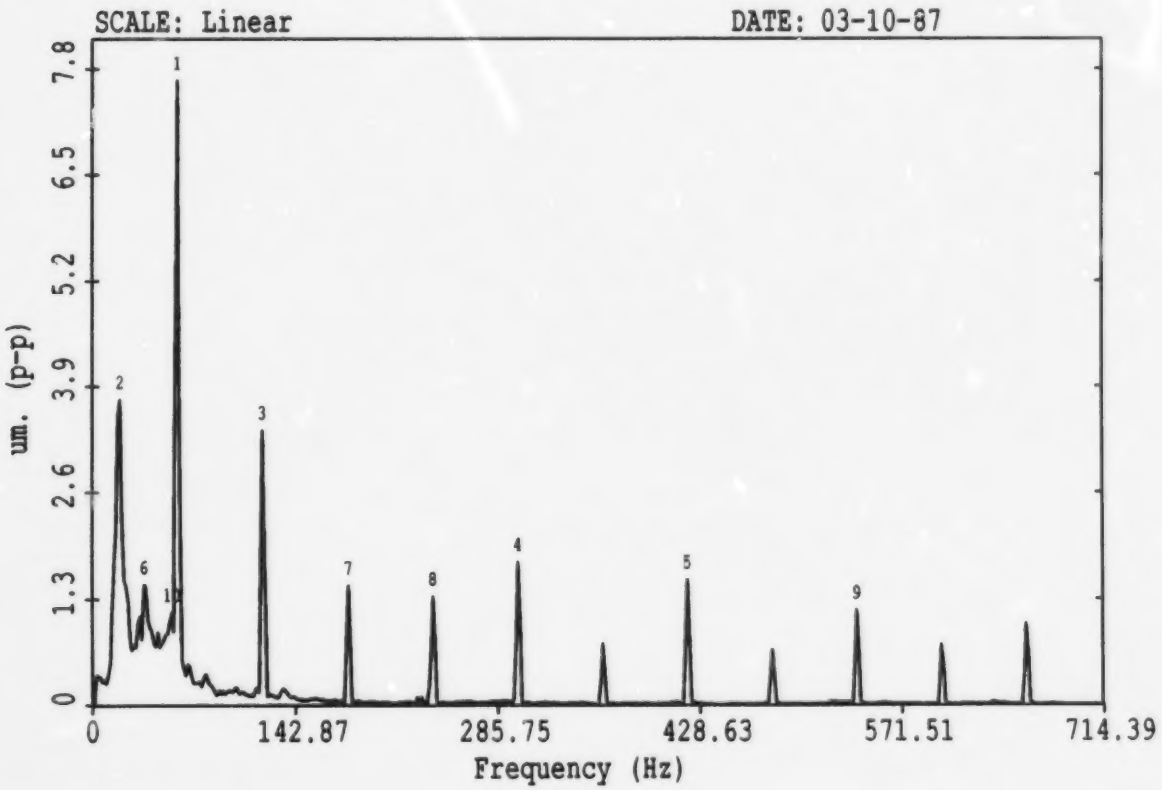

FIGURE 97

Darlington GS Standby Generator #4 Power Turbine

SIGNAL : Outboard Brg. Shaft Displacement Y-Axis
SPEED : 3600 r.p.m.
PROCESS CONDITION : Load 13 MW

PEAK NO.	FREQUENCY	ORDER	AMPLITUDE
1	60.0	1.00	28.20
2	19.5	0.33	11.67
3	15.3	0.26	6.57
4	120.0	2.00	4.88
5	36.3	0.60	3.94
6	54.4	0.91	3.58
7	32.1	0.53	3.05
8	180.0	3.00	2.90
9	46.0	0.77	2.68
10	29.3	0.49	2.40

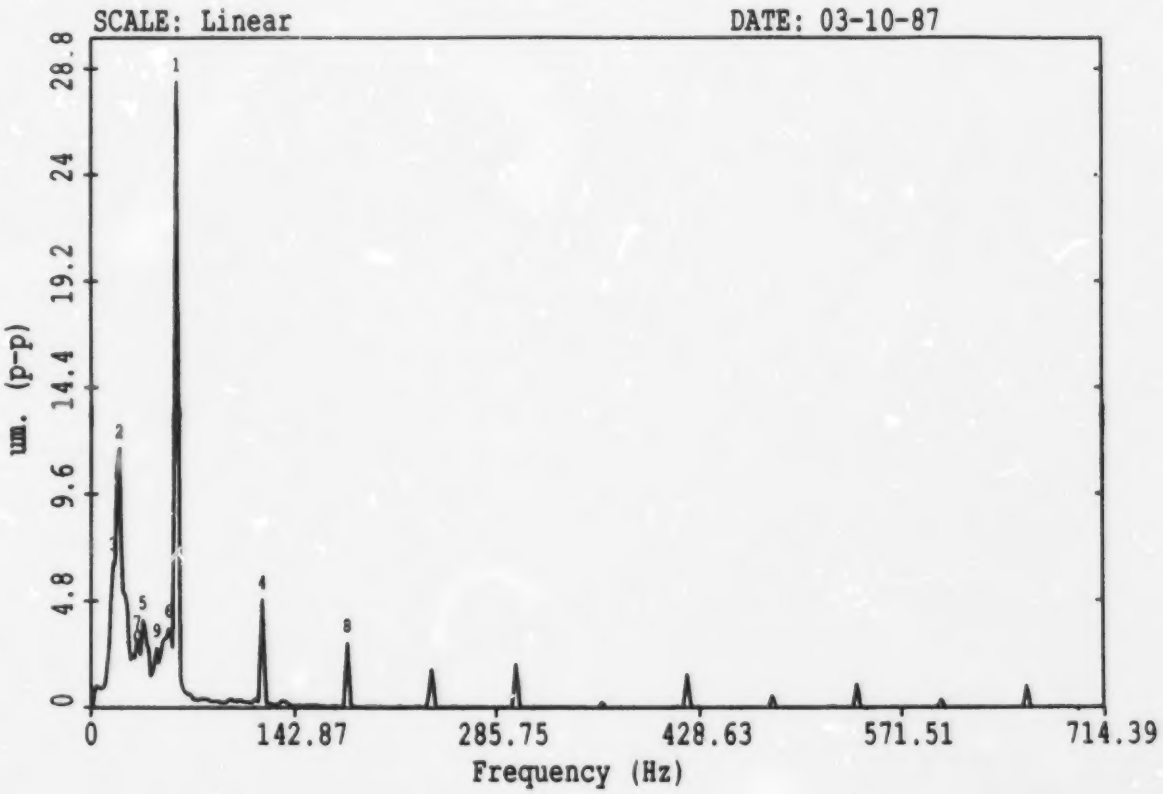

FIGURE 98
89-6

Darlington GS Standby Generator #4 Power Turbine

SIGNAL : Inboard Brg. Shaft Displacement X-Axis
SPEED : 3600 r.p.m.
PROCESS CONDITION : Load 20 MW

PEAK NO.	FREQUENCY	ORDER	AMPLITUDE
1	60.0	1.00	34.81
2	120.0	2.00	6.43
3	180.0	3.00	2.84
4	32.1	0.53	2.69
5	40.5	0.67	2.63
6	15.3	0.26	2.31
7	36.3	0.60	1.78
8	240.0	4.00	1.60
9	50.2	0.84	1.39
10	23.7	0.40	1.38

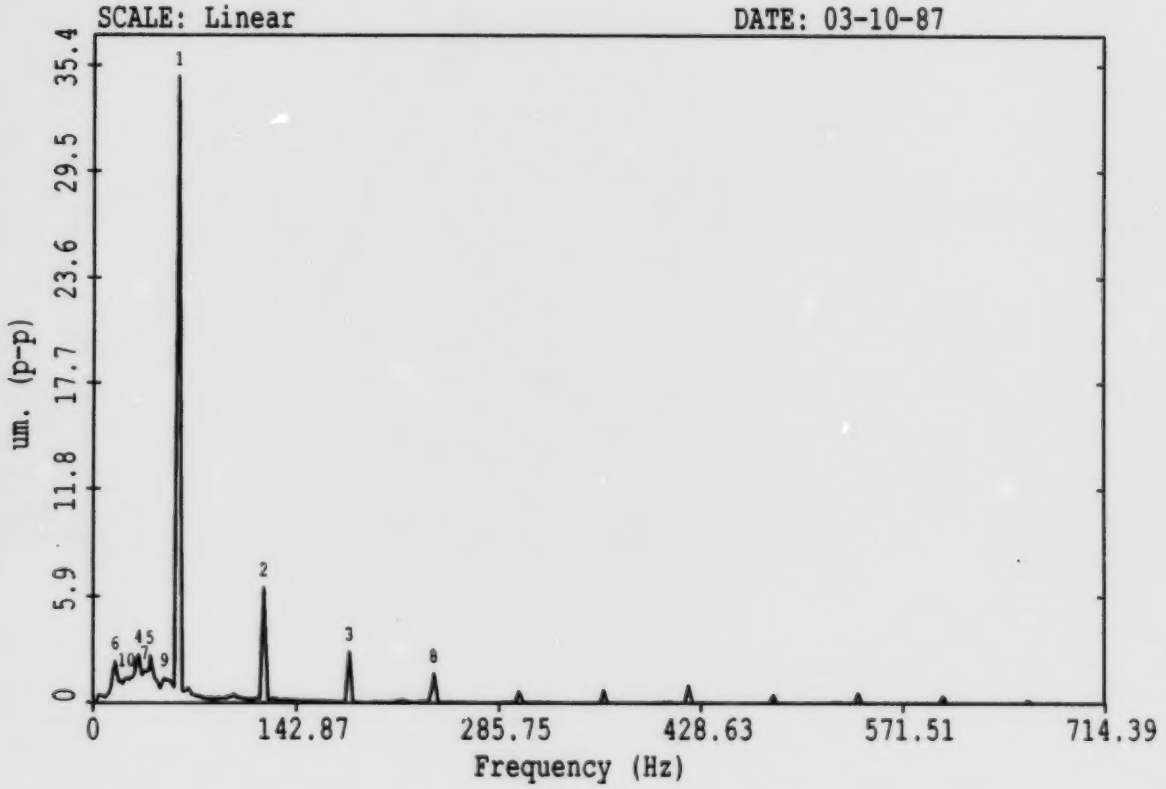

FIGURE 99

Darlington GS Standby Generator #4 Power Turbine

SIGNAL : Inboard Brg. Shaft Displacement Y-Axis
SPEED : 3600 r.p.m.
PROCESS CONDITION : Load 20 MW

PEAK NO.	FREQUENCY	ORDER	AMPLITUDE
1	60.0	1.00	42.74
2	120.0	2.00	6.22
3	32.1	0.53	4.82
4	40.5	0.67	4.05
5	15.3	0.26	3.91
6	36.3	0.60	2.88
7	180.0	3.00	2.72
8	23.7	0.40	2.14
9	50.2	0.84	1.85
10	240.0	4.00	1.83

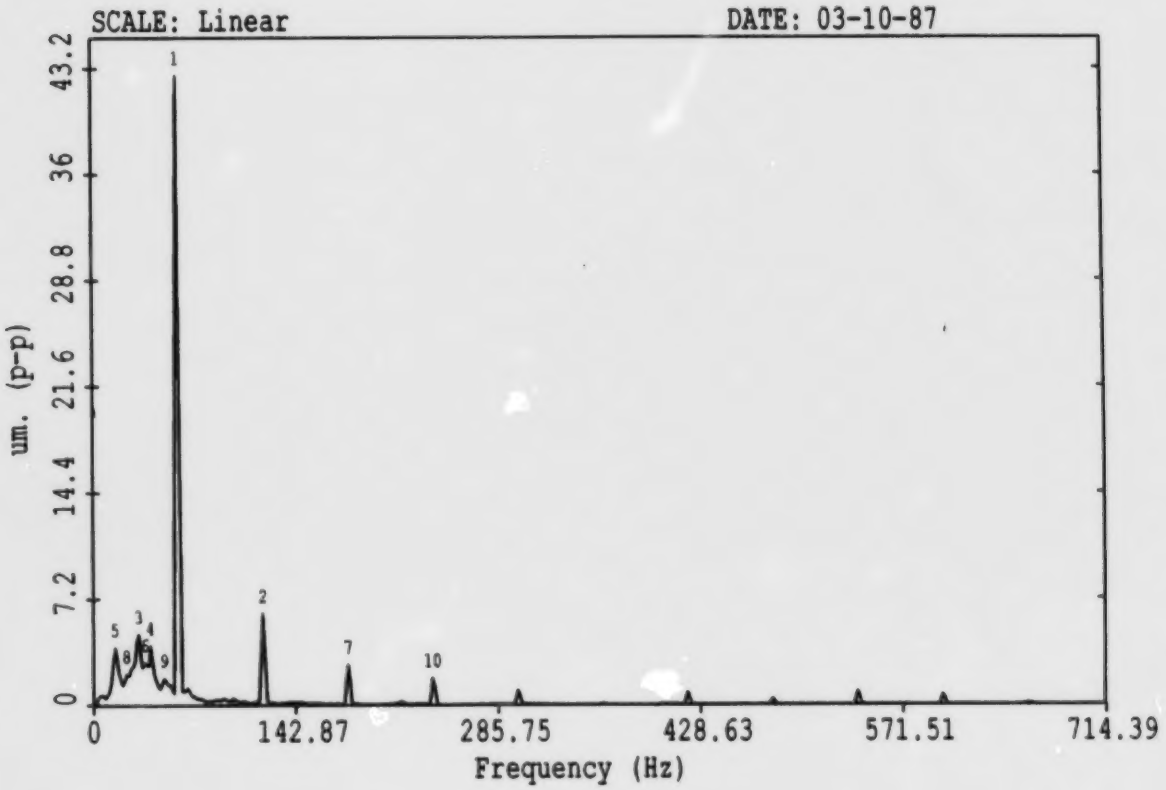

FIGURE 100

Darlington GS Standby Generator #4 Power Turbine

SIGNAL : Outboard Brg. Shaft Displacement X-Axis
SPEED : 3600 r.p.m.
PROCESS CONDITION : Load 20 MW

PEAK NO.	FREQUENCY	ORDER	AMPLITUDE
1	60.0	1.00	6.48
2	19.5	0.33	3.97
3	120.0	2.00	3.76
4	300.0	5.00	1.81
5	420.0	7.00	1.62
6	180.0	3.00	1.45
7	660.0	11.00	1.25
8	240.0	4.00	1.18
9	540.0	9.00	1.16
10	34.9	0.58	1.13

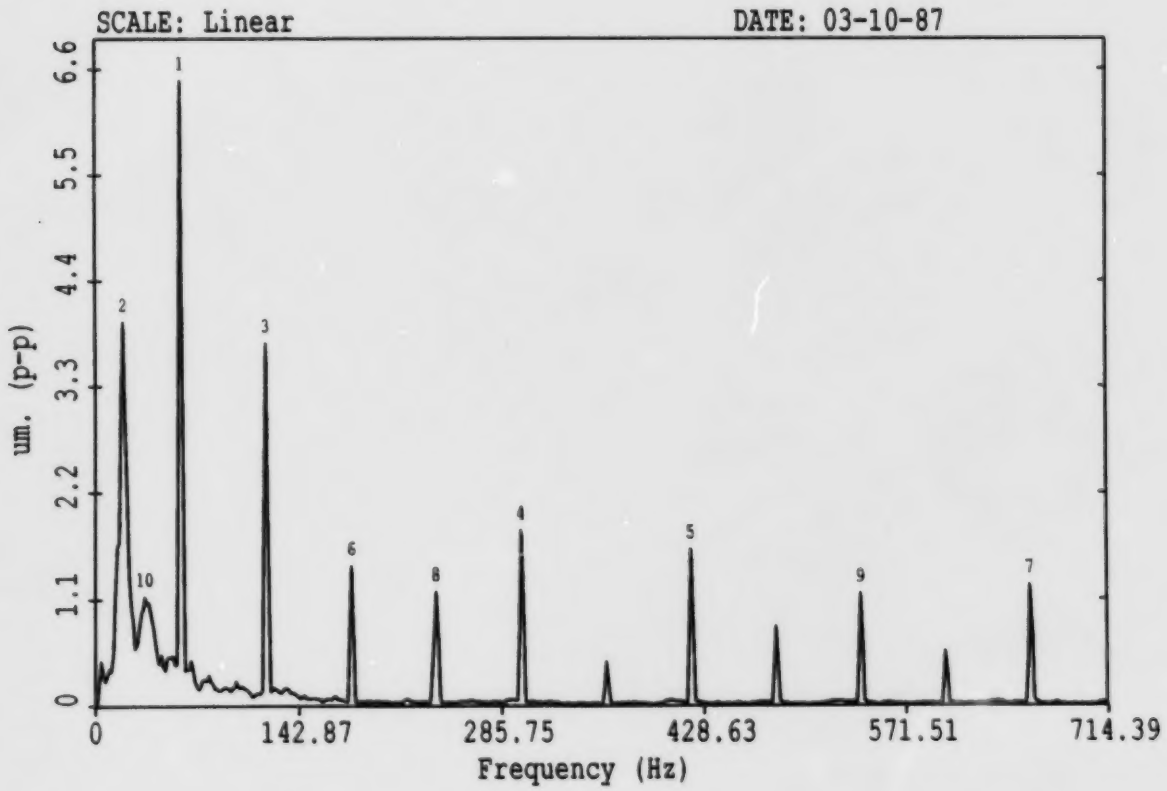

FIGURE 101

Darlington GS Standby Generator #4 Power Turbine

SIGNAL : Outboard Brg. Shaft Displacement Y-Axis
SPEED : 3600 r.p.m.
PROCESS CONDITION : Load 20 MW

PEAK NO.	FREQUENCY	ORDER	AMPLITUDE
1	60.0	1.00	28.02
2	19.5	0.33	12.76
3	15.3	0.26	6.87
4	120.0	2.00	5.38
5	32.1	0.53	3.23
6	34.9	0.58	2.83
7	180.0	3.00	2.83
8	40.5	0.67	2.29
9	300.0	5.00	2.16
10	46.0	0.77	1.72

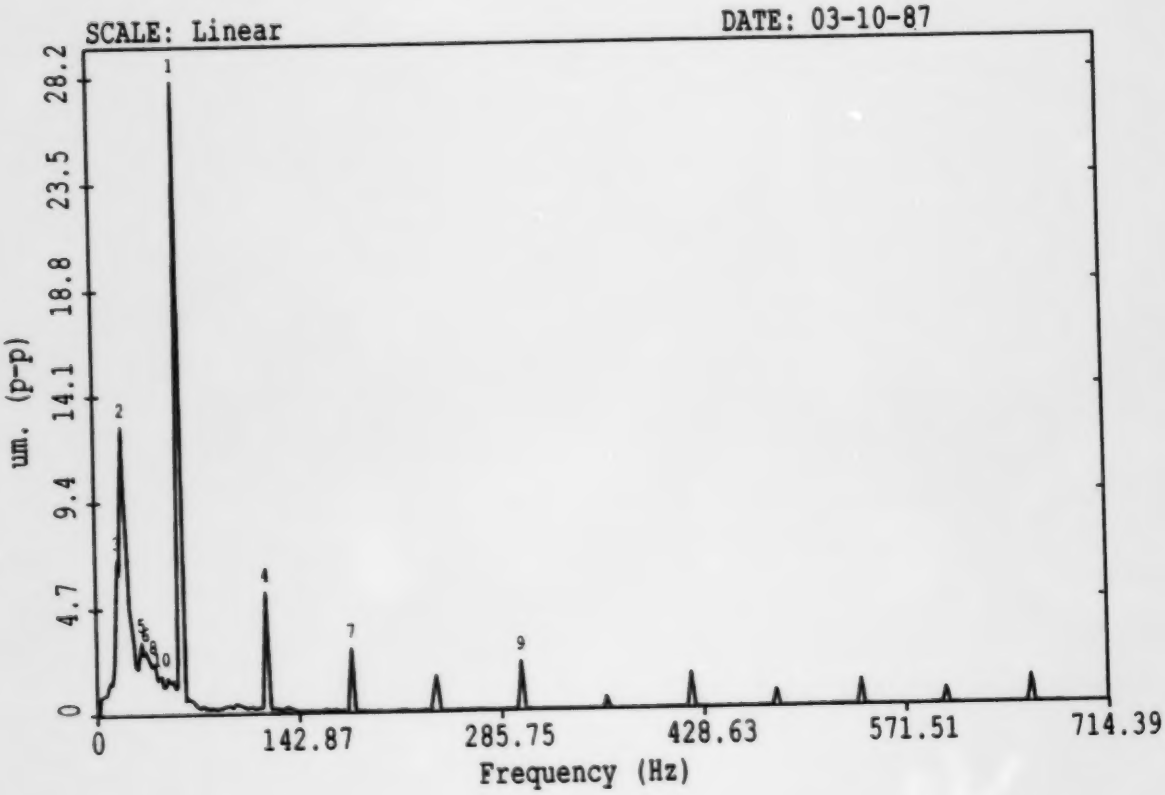

FIGURE 102

Darlington GS Standby Generator #4 Power Turbine

SIGNAL : Inboard Brg. Shaft Displacement X-Axis
SPEED : 3600 r.p.m.
PROCESS CONDITION : Load 26 MW

PEAK NO.	FREQUENCY	ORDER	AMPLITUDE
1	60.0	1.00	30.04
2	120.0	2.00	6.58
3	180.0	3.00	2.71
4	30.7	0.51	2.54
5	15.3	0.26	2.21
6	41.9	0.70	1.97
7	36.3	0.60	1.90
8	23.7	0.40	1.60
9	240.0	4.00	1.53
10	48.8	0.81	1.10

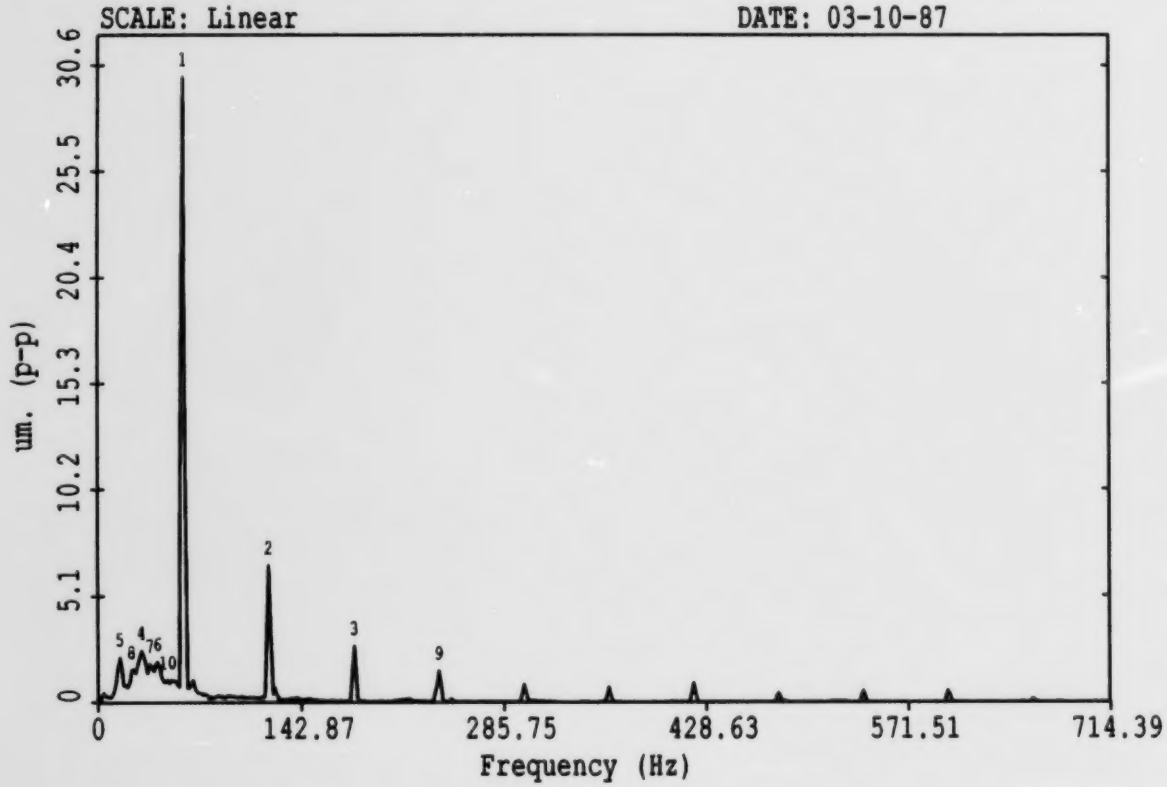

FIGURE 103

Darlington GS Standby Generator #4 Power Turbine

SIGNAL : Inboard Brg. Shaft Displacement Y-Axis
SPEED : 3600 r.p.m.
PROCESS CONDITION : Load 26 MW

PEAK NO.	FREQUENCY	ORDER	AMPLITUDE
1	60.0	1.00	35.46
2	120.0	2.00	6.27
3	30.7	0.51	4.30
4	15.3	0.26	3.88
5	36.3	0.60	3.28
6	41.9	0.70	2.97
7	180.0	3.00	2.72
8	25.1	0.42	2.61
9	240.0	4.00	1.81
10	67.0	1.12	1.41

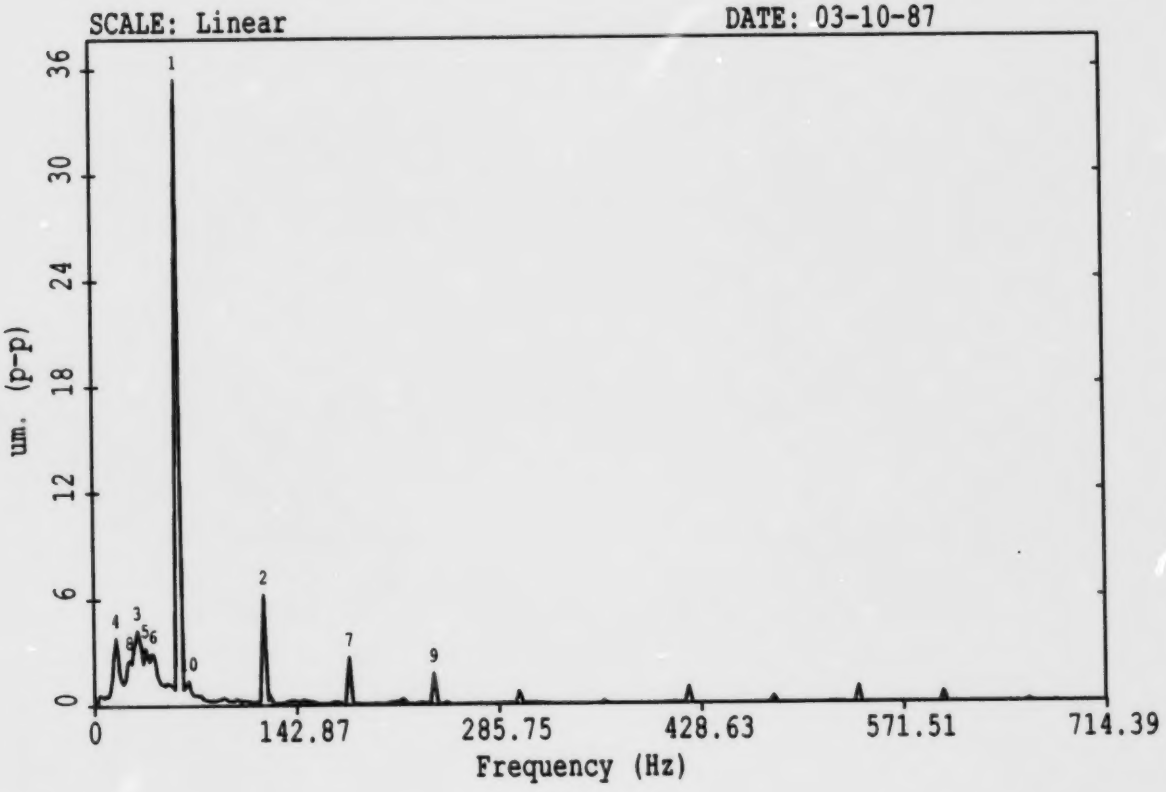

FIGURE 104

Darlington GS Standby Generator #4 Power Turbine

SIGNAL : Outboard Brg. Shaft Displacement X-Axis
SPEED : 3600 r.p.m.
PROCESS CONDITION : Load 26 MW

PEAK NO.	FREQUENCY	ORDER	AMPLITUDE
1	60.0	1.00	5.74
2	120.0	2.00	4.02
3	19.5	0.33	3.13
4	23.7	0.40	2.04
5	36.3	0.60	1.70
6	420.0	7.00	1.64
7	300.0	5.00	1.62
8	180.0	3.00	1.38
9	660.0	11.00	1.27
10	240.0	4.00	1.16

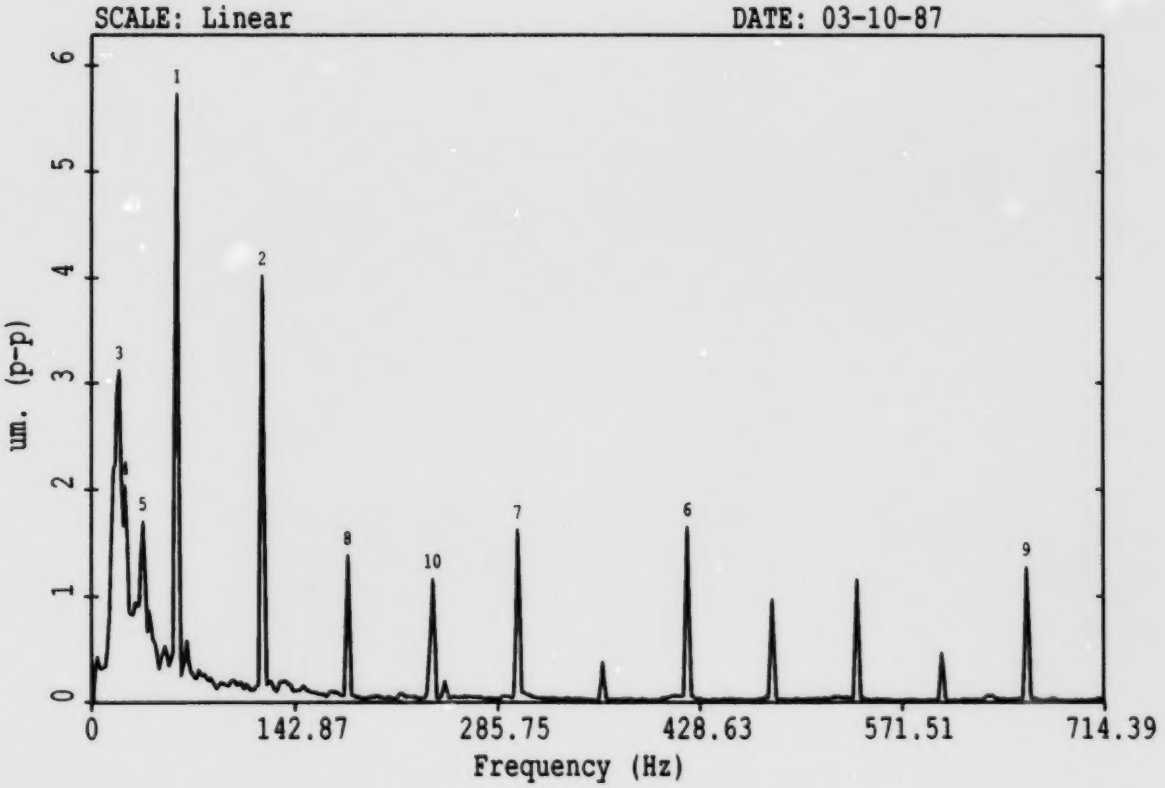

FIGURE 105

Darlington GS Standby Generator #4 Power Turbine

SIGNAL : Outboard Brg. Shaft Displacement Y-Axis
SPEED : 3600 r.p.m.
PROCESS CONDITION : Load 26 MW

PEAK NO.	FREQUENCY	ORDER	AMPLITUDE
1	60.0	1.00	29.74
2	19.5	0.33	9.36
3	15.3	0.26	7.34
4	23.7	0.40	6.89
5	120.0	2.00	5.77
6	36.3	0.60	4.24
7	30.7	0.51	3.44
8	180.0	3.00	2.83
9	40.5	0.67	2.19
10	300.0	5.00	2.05

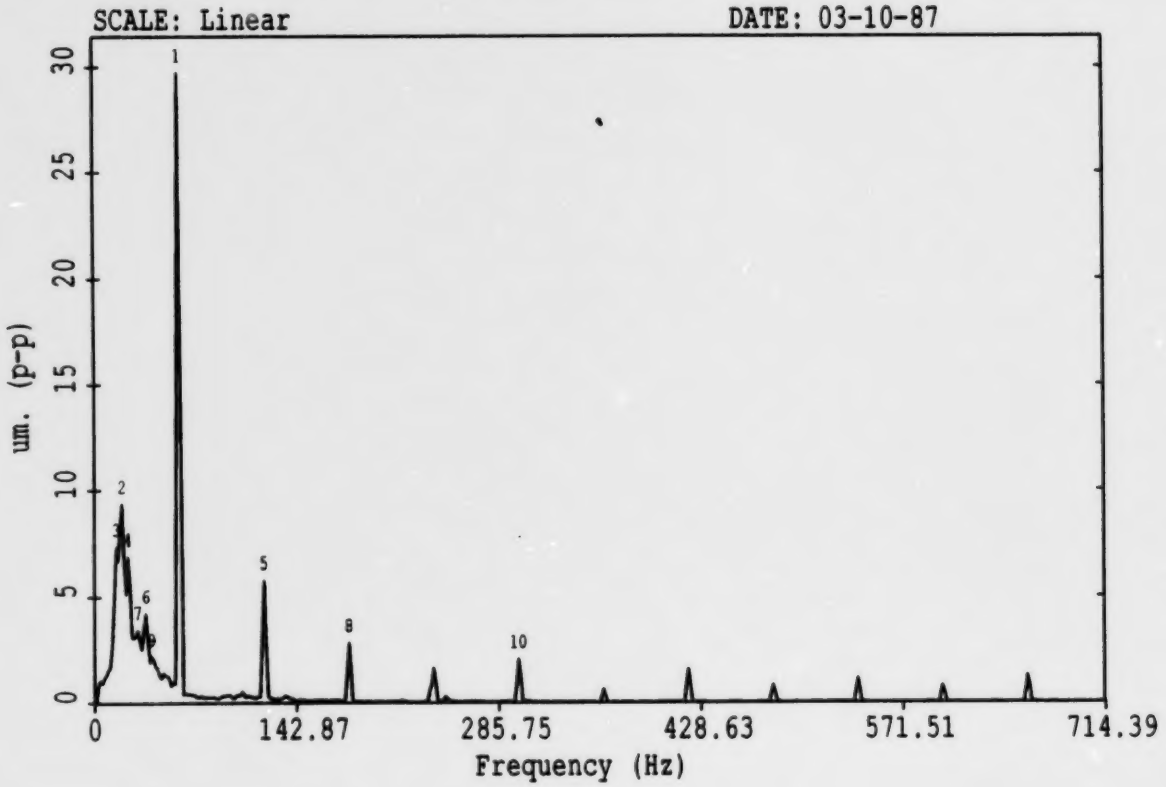

FIGURE 106

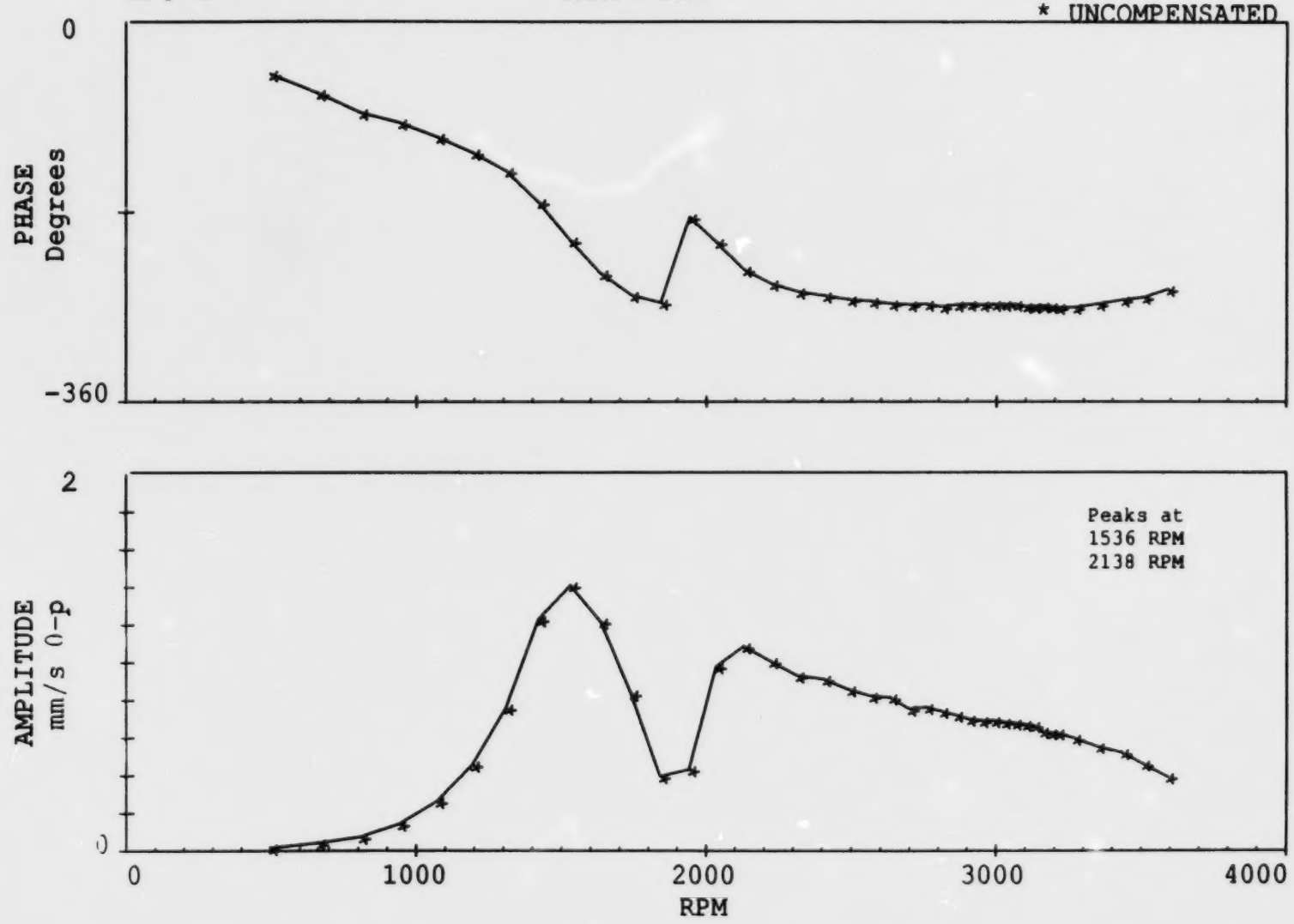
Darlington GS Standby Generator #4 - Cold Start
AC Generator Outboard Brg. Casing Velocity X-Axis
BODE PLOT : Run-up
Ch # 2
Date : 06-Mar-1987
Order : 1.00
* UNCOMPENSATED
0
PHASE
Degrees
-360
2
AMPLITUDE
mm/s 0-p
0
Peaks at
1536 RPM
2138 RPM
0
1000
2000
3000
4000
RPM

FIGURE 107

Darlington GS Standby Generator #4 - Cold Start
AC Generator Outboard Brg. Casing Velocity Y-Axis

BODE PLOT : Run-up
Ch # 1

Date : 06-Mar-1987
Order : 1.00

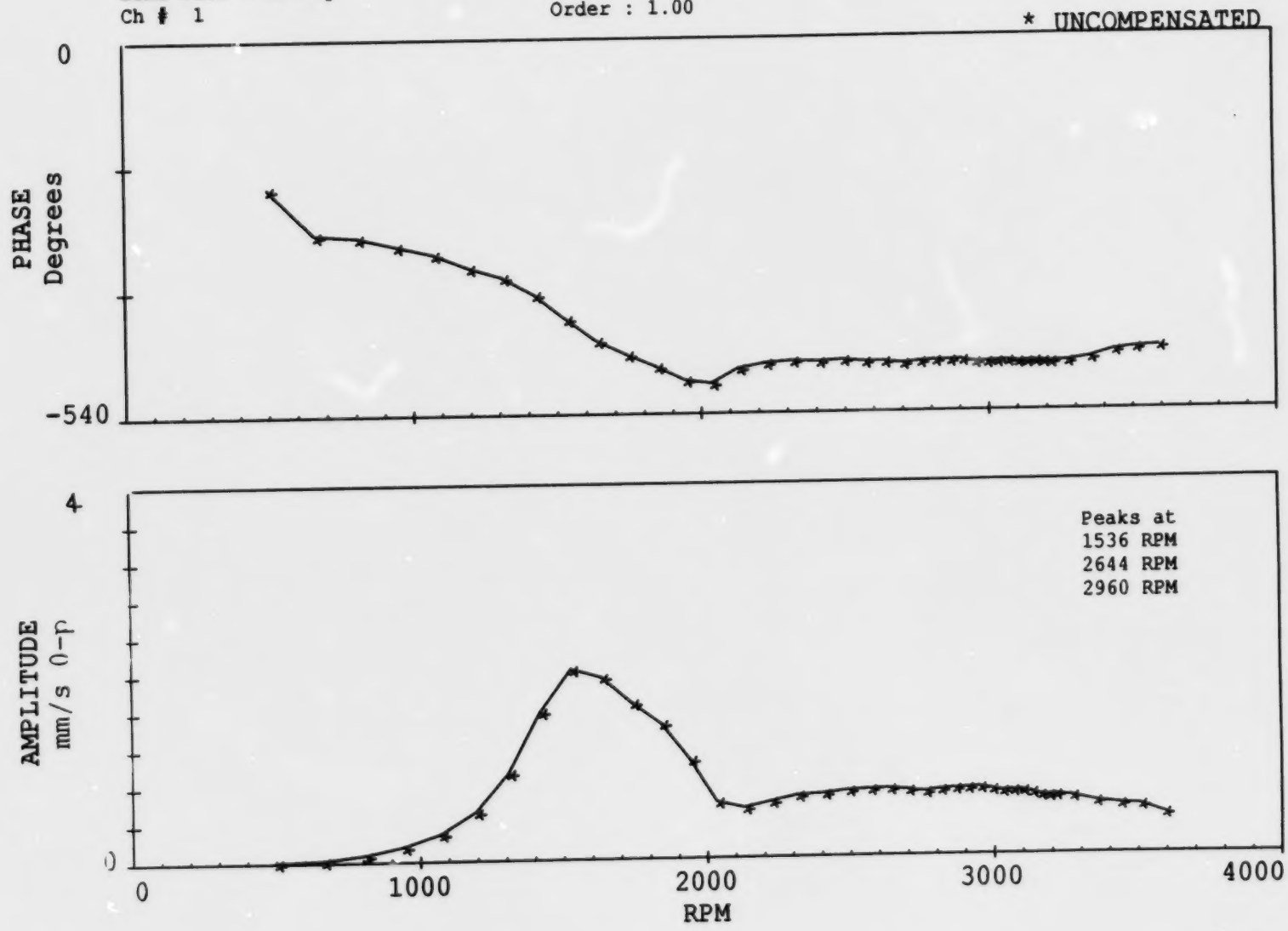

FIGURE 108

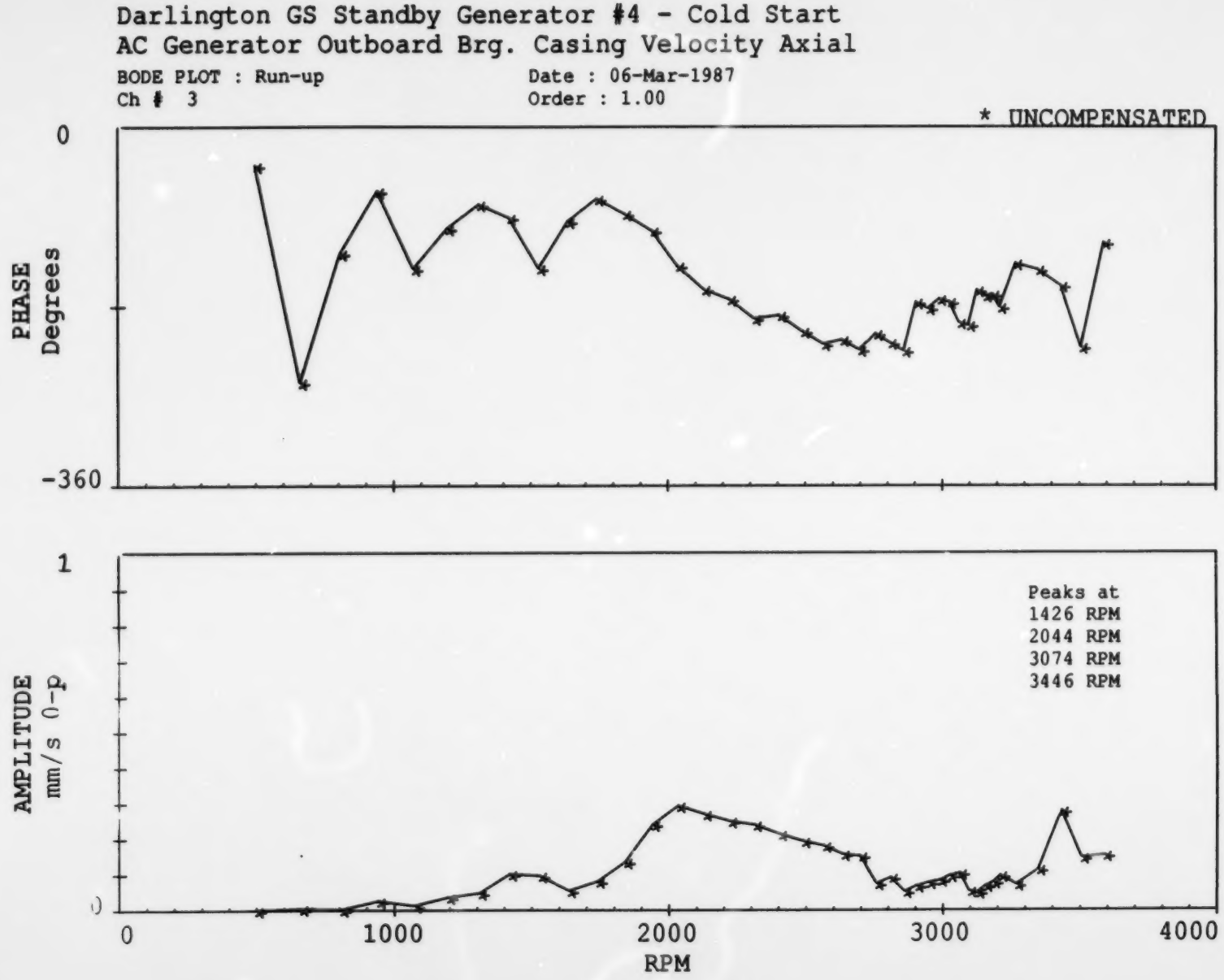
Darlington GS Standby Generator #4 - Cold Start
AC Generator Outboard Brg. Casing Velocity Axial
BODE PLOT : Run-up
Ch # 3
Date : 06-Mar-1987
Order : 1.00
* UNCOMPENSATED
0
PHASE
Degrees
-360
1
AMPLITUDE
mm/s 0-p
0
Peaks at
1426 RPM
2044 RPM
3074 RPM
3446 RPM
1000
2000
3000
4000
RPM

FIGURE 109

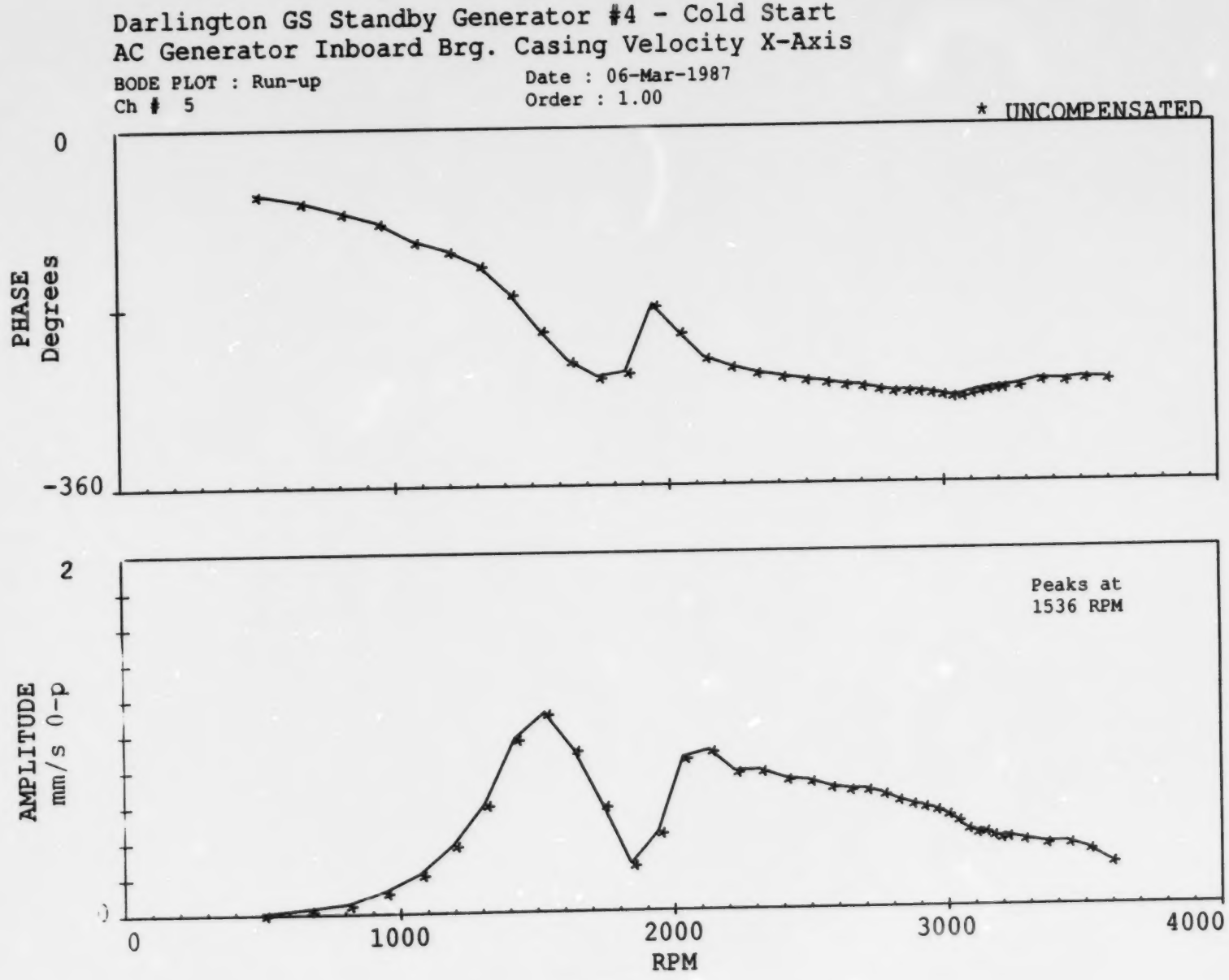
Darlington GS Standby Generator #4 - Cold Start
AC Generator Inboard Brg. Casing Velocity X-Axis
BODE PLOT : Run-up
Ch # 5
Date : 06-Mar-1987
Order : 1.00
* UNCOMPENSATED
0
PHASE
Degrees
-360
2
AMPLITUDE
mm/s 0-p
Peaks at
1536 RPM
0
1000
2000
3000
4000
RPM

FIGURE 110

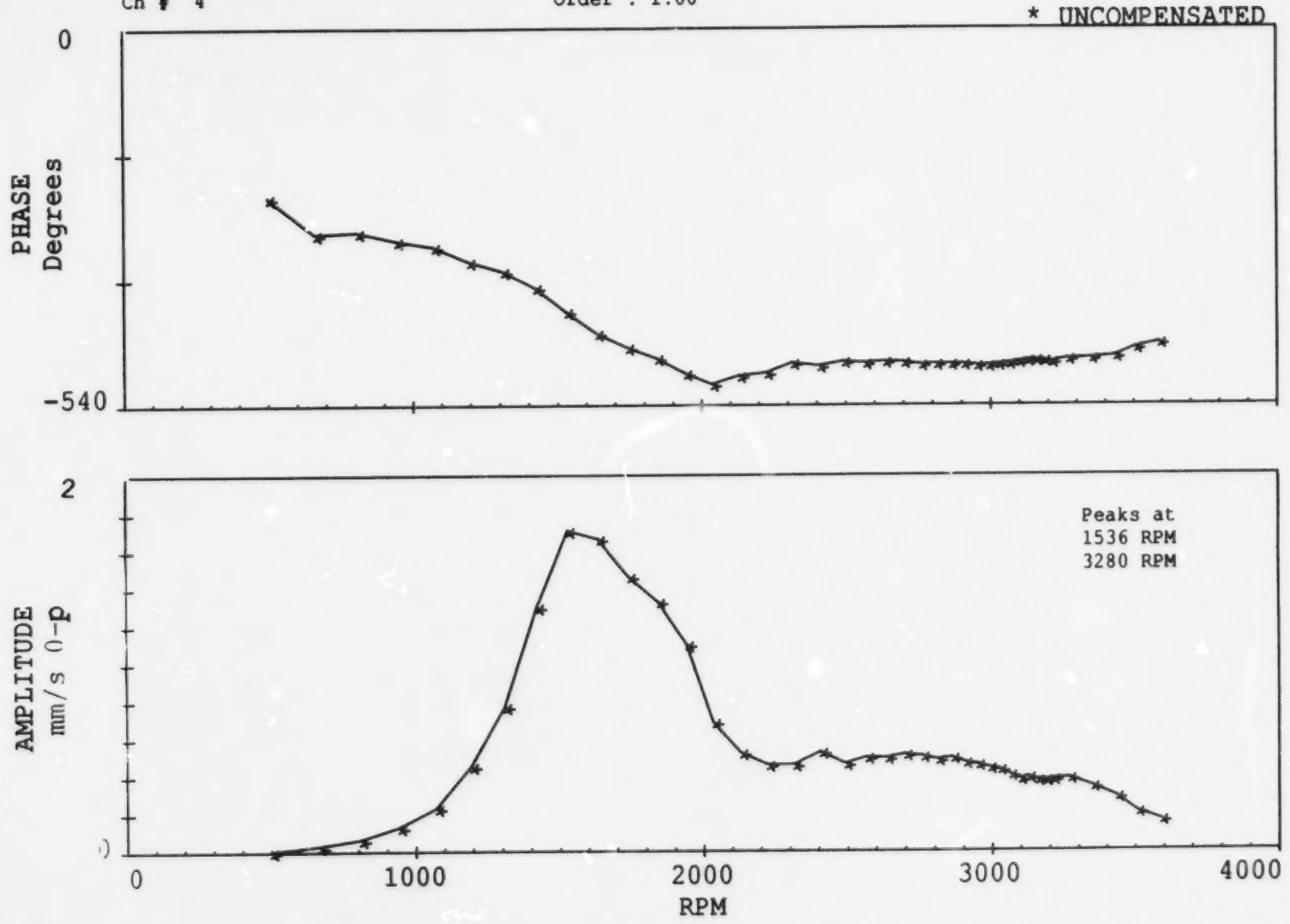
Darlington GS Standby Generator #4 - Cold Start
AC Generator Inboard Brg. Casing Velocity Y-Axis
BODE PLOT : Run-up
Ch # 4
Date : 06-Mar-1987
Order : 1.00
* UNCOMPENSATED
0
PHASE
Degrees
-540
2
AMPLITUDE
mm/s 0-p
Peaks at
1536 RPM
3280 RPM
0
1000
2000
3000
4000
RPM

FIGURE 111

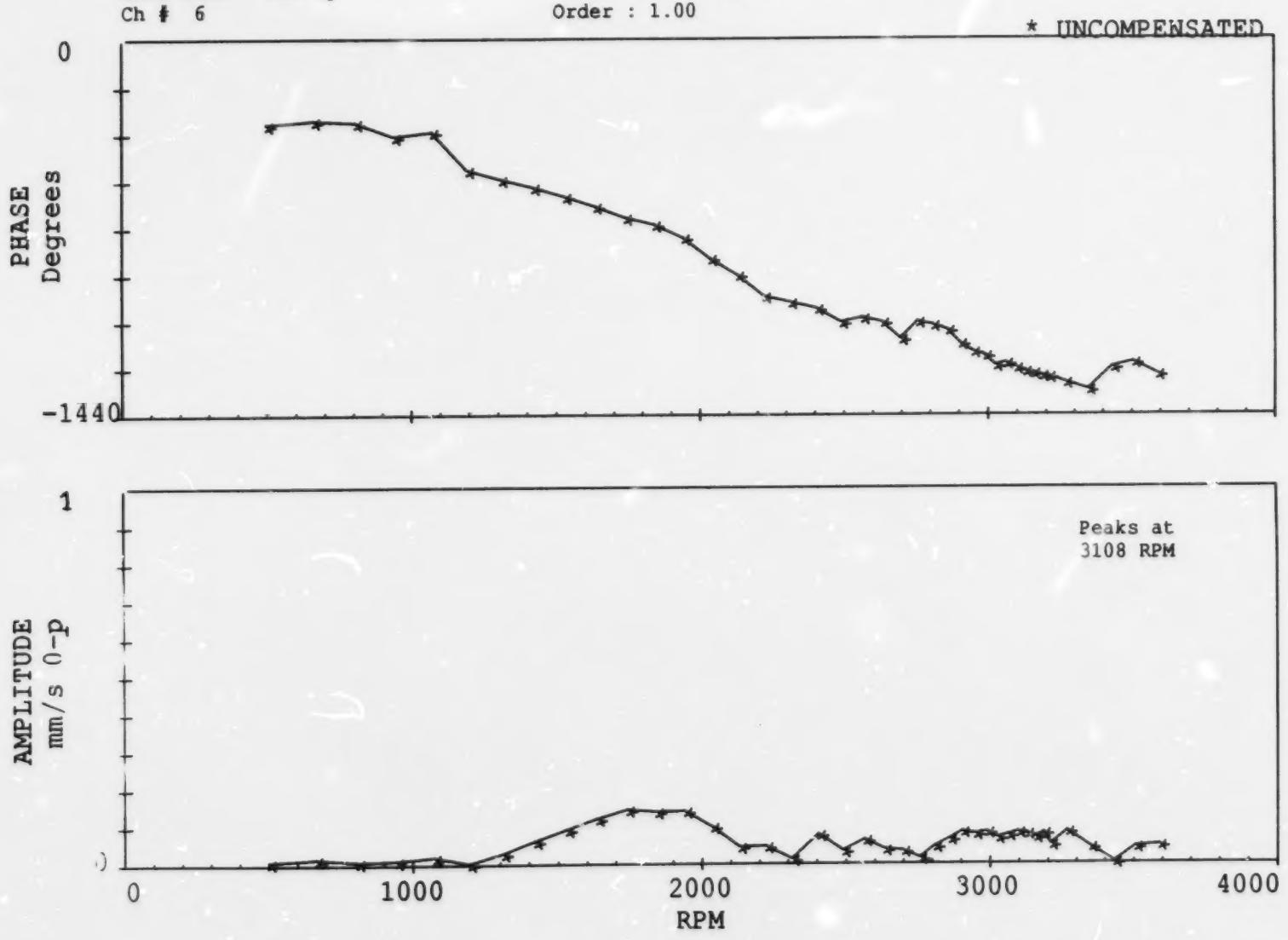
Darlington GS Standby Generator #4 - Cold Start
AC Generator Inboard Brg. Casing Velocity Axial
BODE PLOT : Run-up
Ch # 6
Date : 06-Mar-1987
Order : 1.00
* UNCOMPENSATED
0
PHASE
Degrees
-1440
1
AMPLITUDE
mm/s 0-p
Peaks at
3108 RPM
0
1000
2000
3000
4000
RPM

FIGURE 112

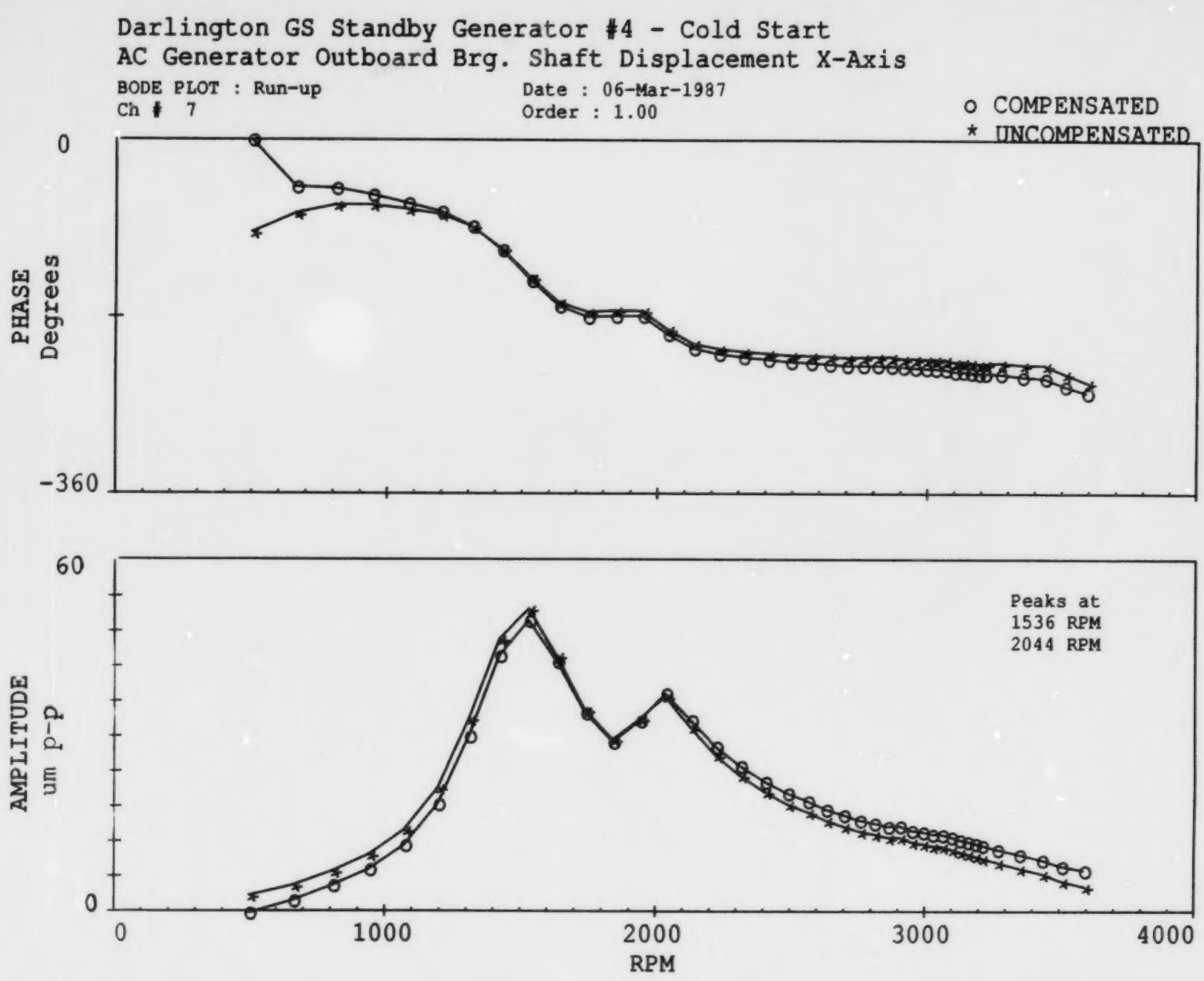

FIGURE 113

89-6

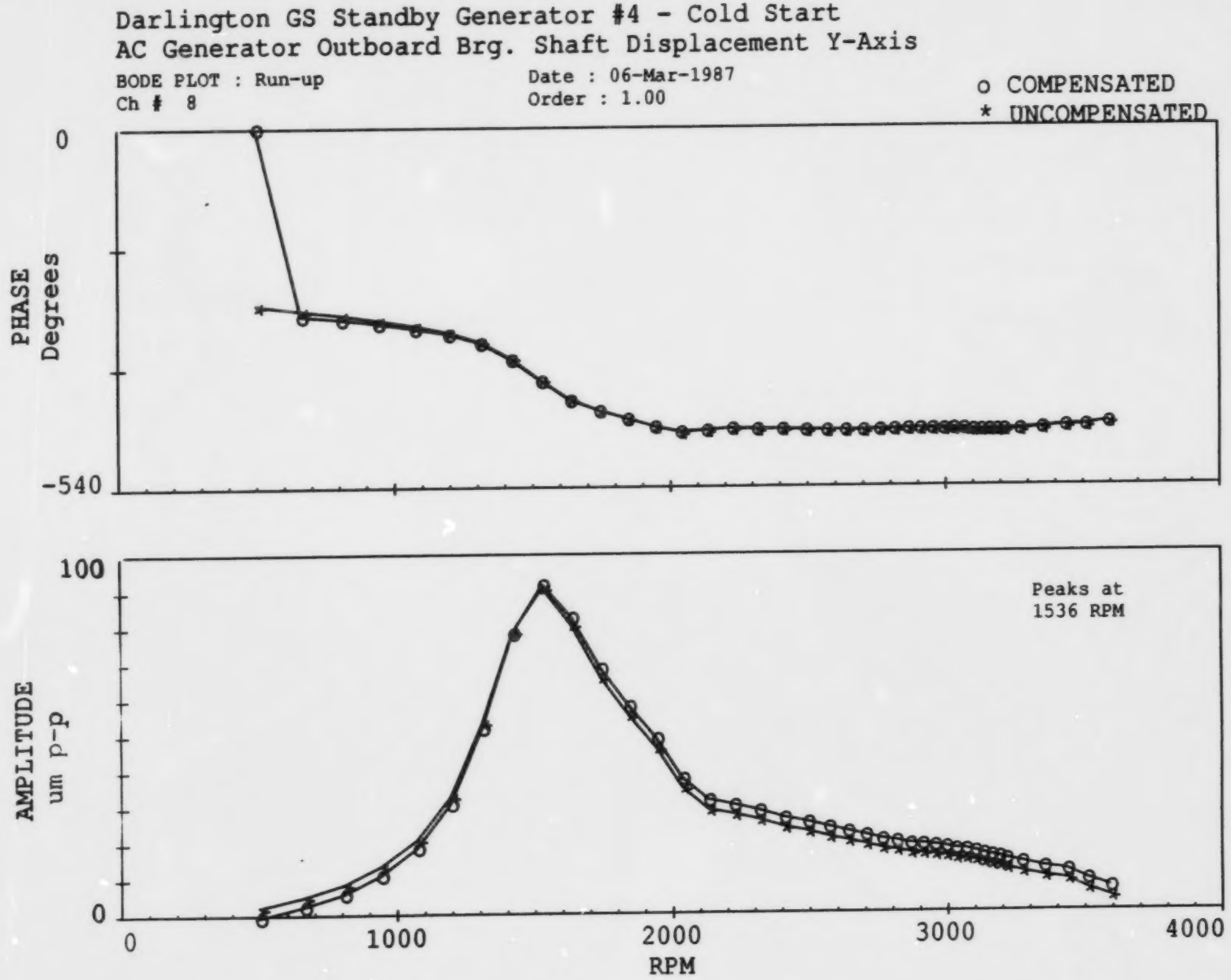
Darlington GS Standby Generator #4 - Cold Start
AC Generator Outboard Brg. Shaft Displacement Y-Axis
BODE PLOT : Run-up
Ch # 8
Date : 06-Mar-1987
Order : 1.00
o COMPENSATED
* UNCOMPENSATED
0
PHASE
Degrees
-540
100
AMPLITUDE
um p-p
0
Peaks at
1536 RPM
0
1000
2000
3000
4000
RPM

FIGURE 114

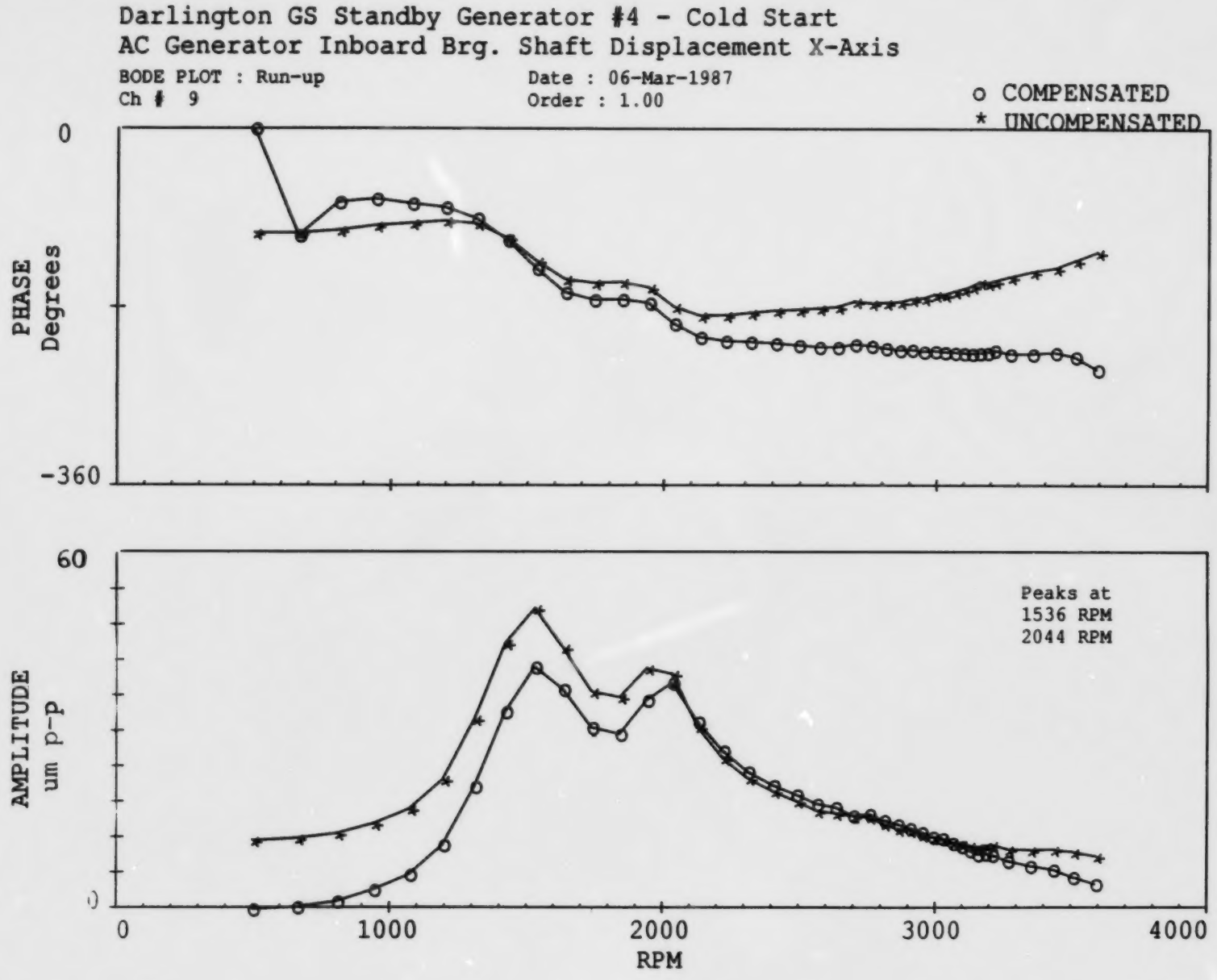

FIGURE 115

89-6

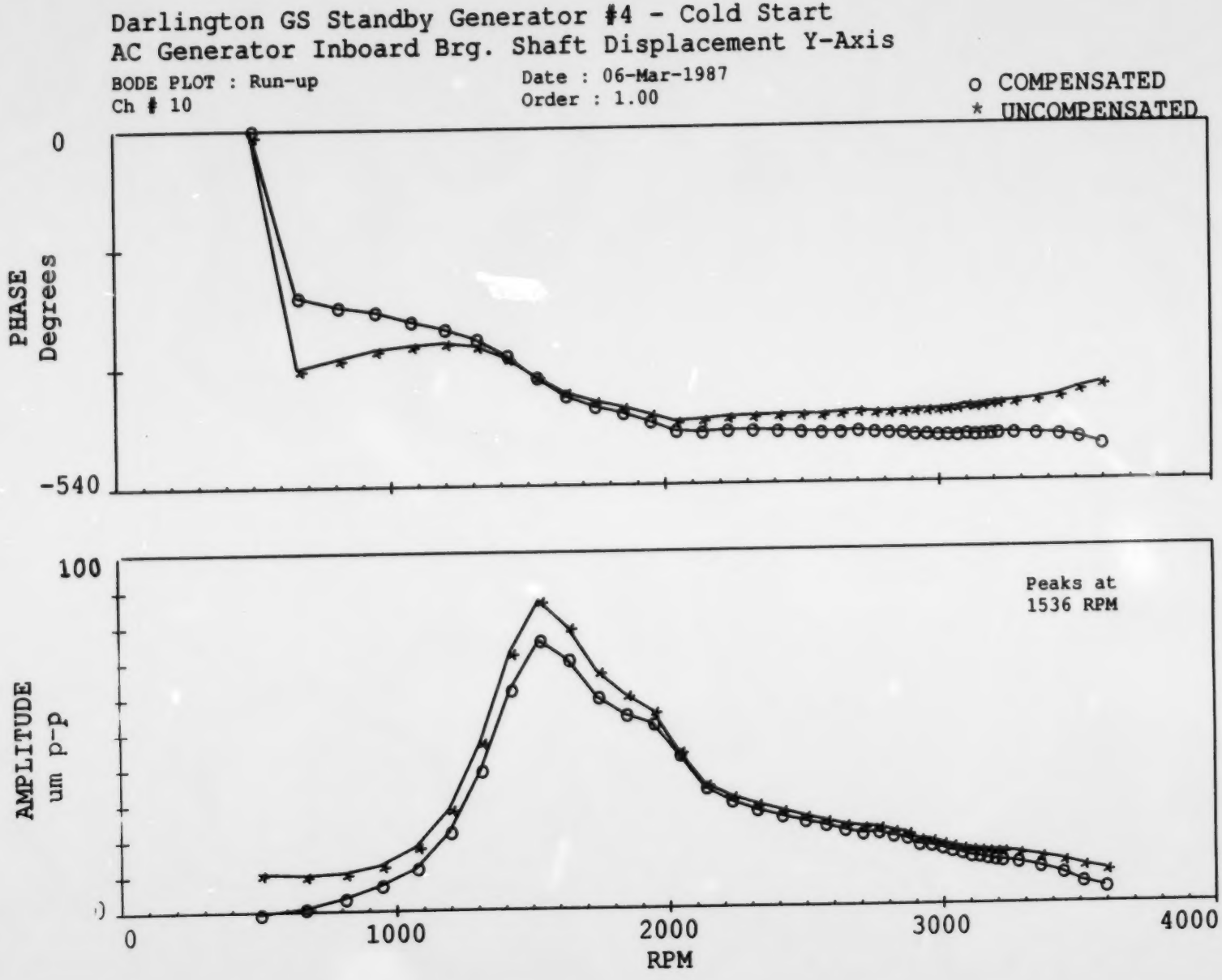
Darlington GS Standby Generator #4 - Cold Start
AC Generator Inboard Brg. Shaft Displacement Y-Axis
BODE PLOT : Run-up
Ch # 10
Date : 06-Mar-1987
Order : 1.00
o COMPENSATED
* UNCOMPENSATED
0
PHASE
Degrees
-540
100
AMPLITUDE
um p-p
Peaks at
1536 RPM
0
1000
2000
3000
4000
RPM

FIGURE 116

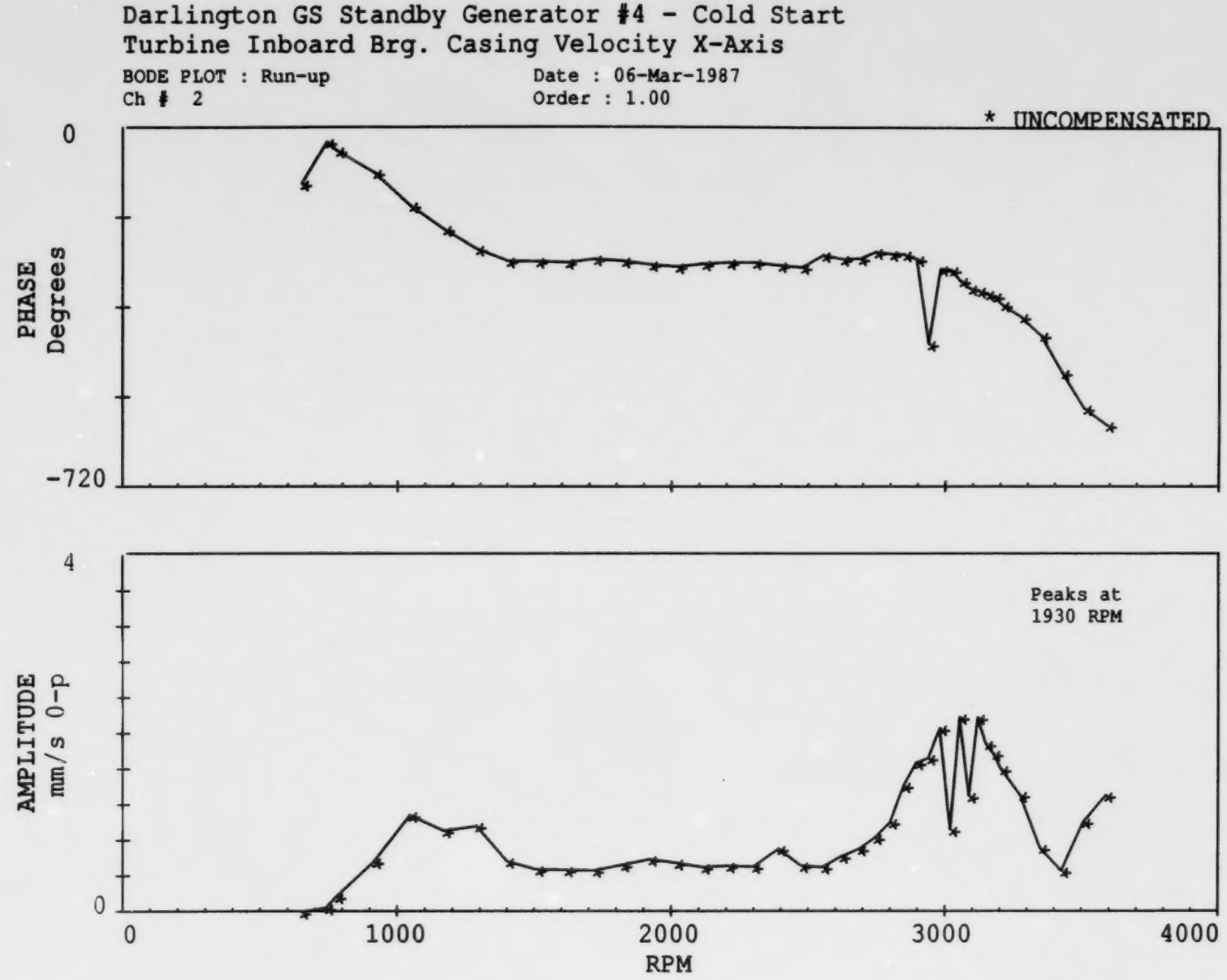
Darlington GS Standby Generator #4 - Cold Start
Turbine Inboard Brg. Casing Velocity X-Axis
BODE PLOT : Run-up
Ch # 2
Date : 06-Mar-1987
Order : 1.00
* UNCOMPENSATED
0
PHASE
Degrees
-720
4
AMPLITUDE
mm/s 0-p
0
Peaks at
1930 RPM
0
1000
2000
3000
4000
RPM

FIGURE 117

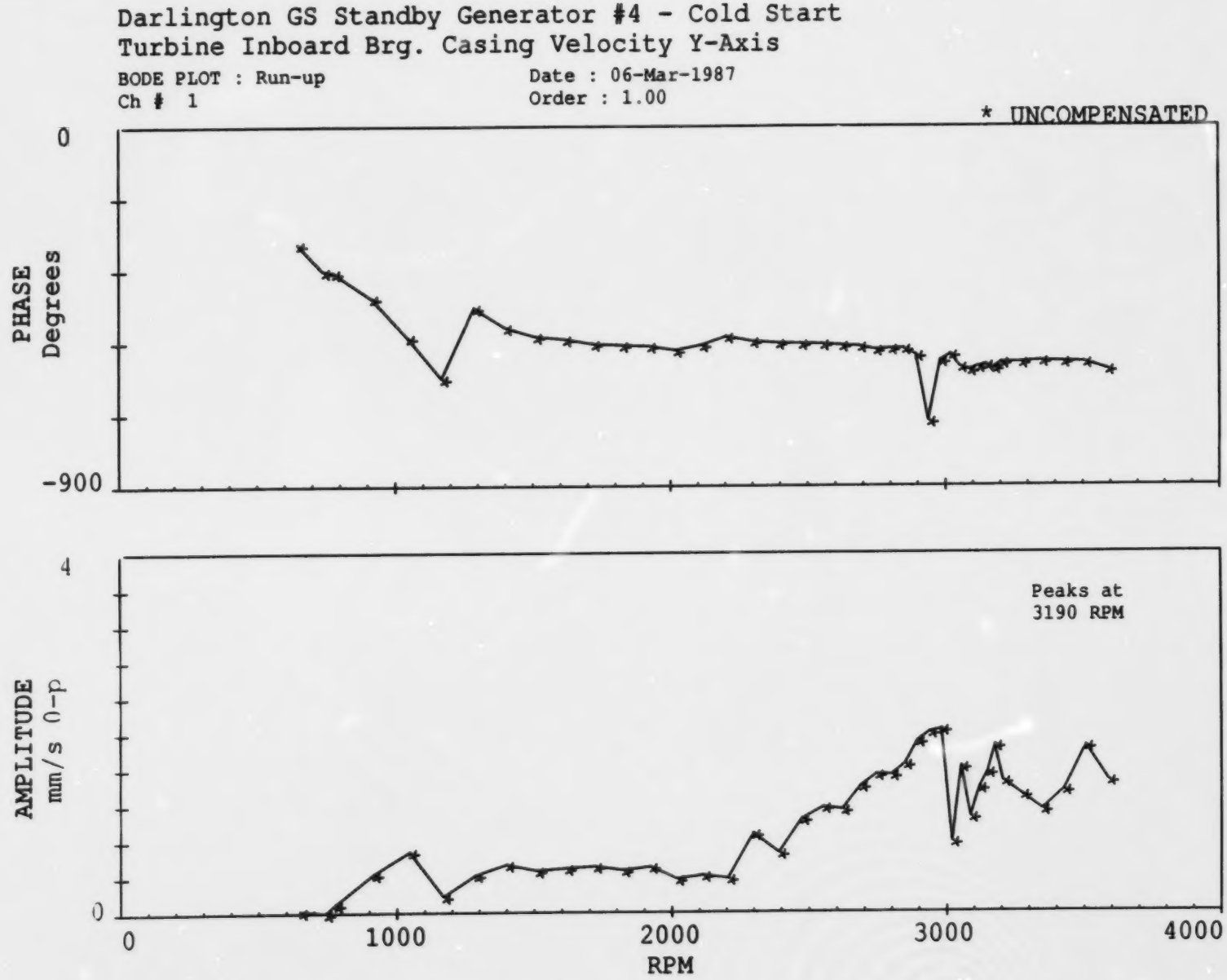
Darlington GS Standby Generator #4 - Cold Start
Turbine Inboard Brg. Casing Velocity Y-Axis
BODE PLOT : Run-up
Ch # 1
Date : 06-Mar-1987
Order : 1.00
* UNCOMPENSATED
0
PHASE
Degrees
-900
4
AMPLITUDE
mm/s 0-p
0
Peaks at
3190 RPM
0
1000
2000
3000
4000
RPM

FIGURE 118

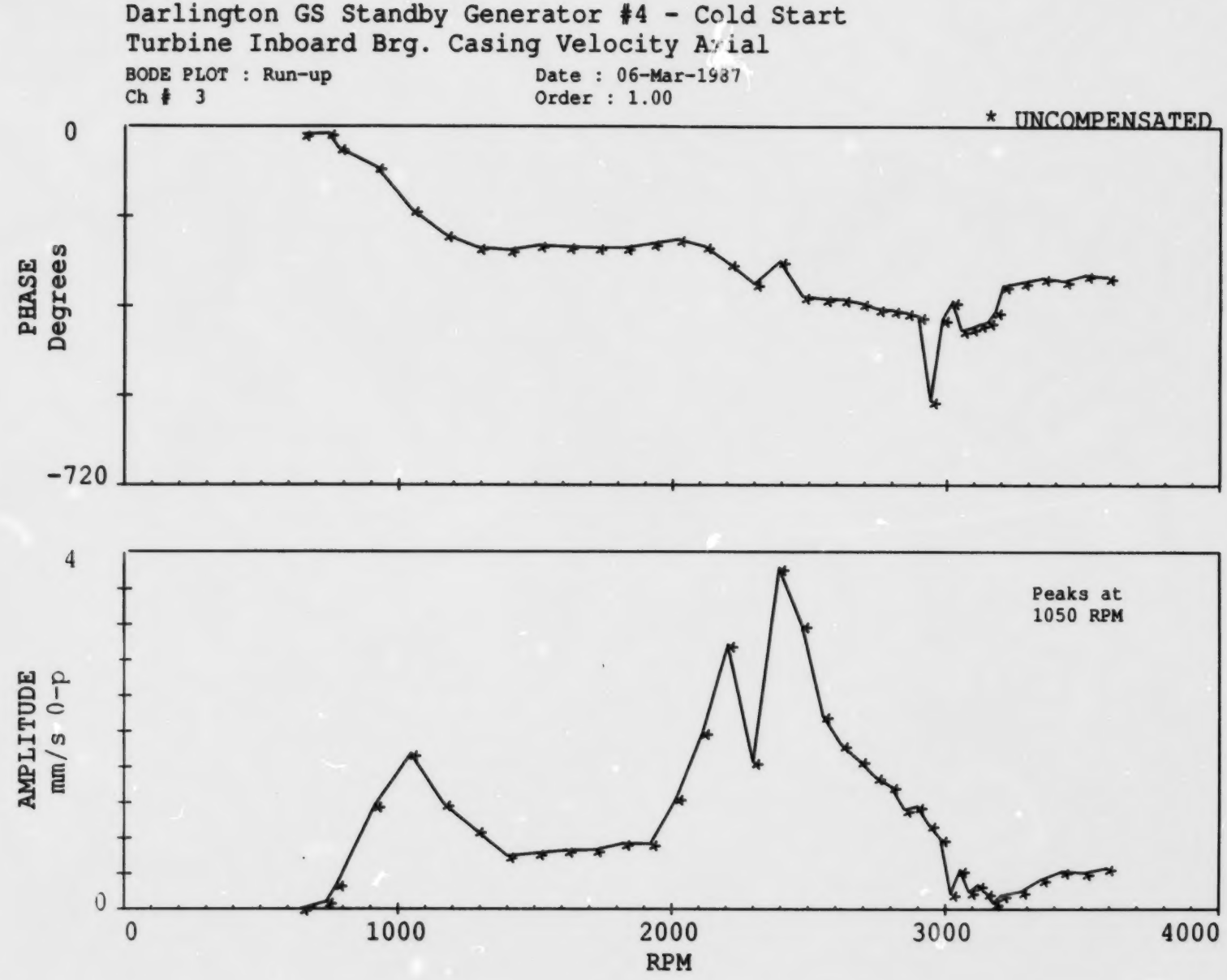

FIGURE 119

89-6

Darlington GS Standby Generator #4 - Cold Start
Turbine Outboard Brg. Casing Velocity Horiz.

BODE PLOT : Run-up
Ch # 5

Date : 06-Mar-1987
Order : 1.00

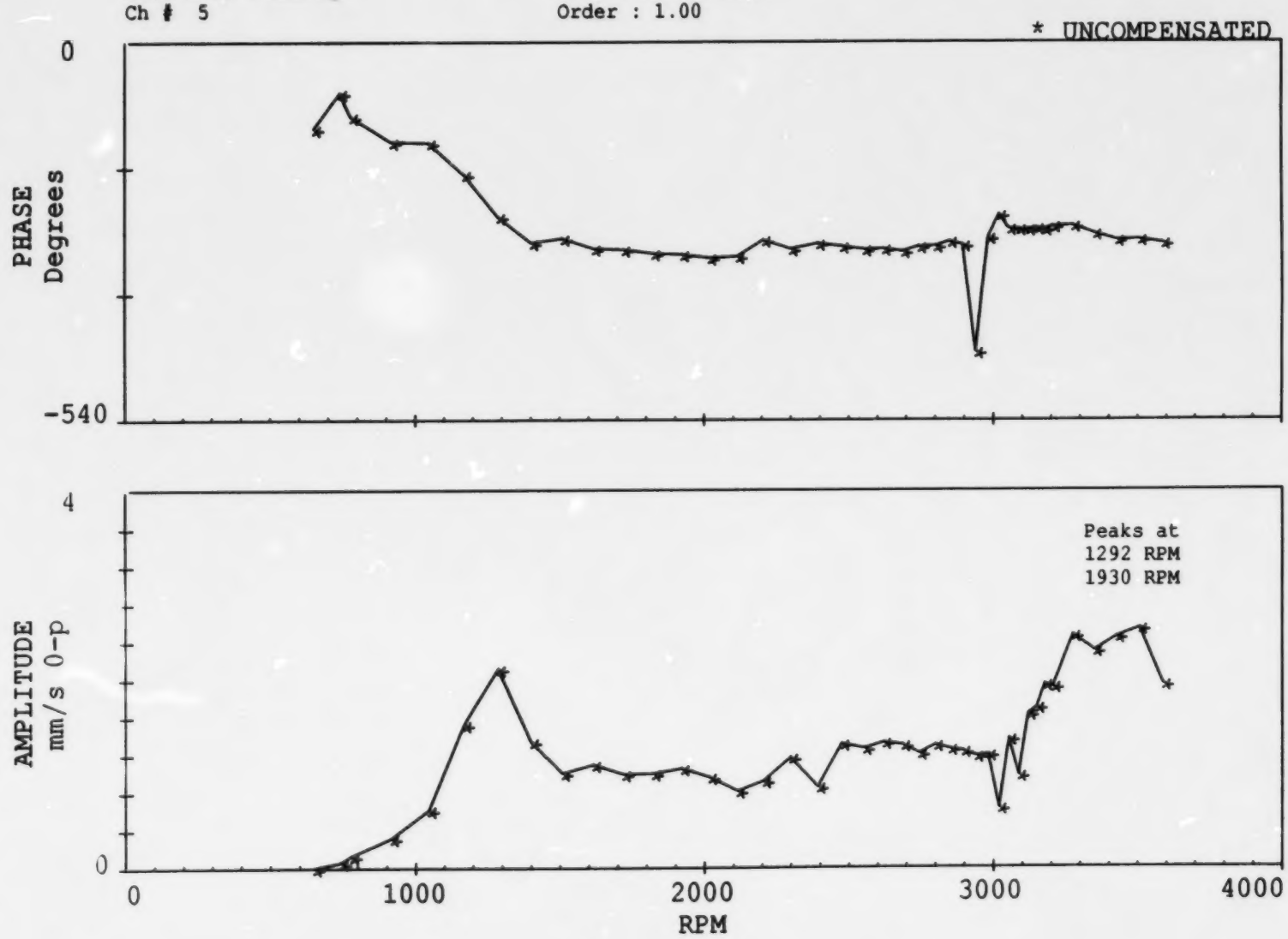

FIGURE 120

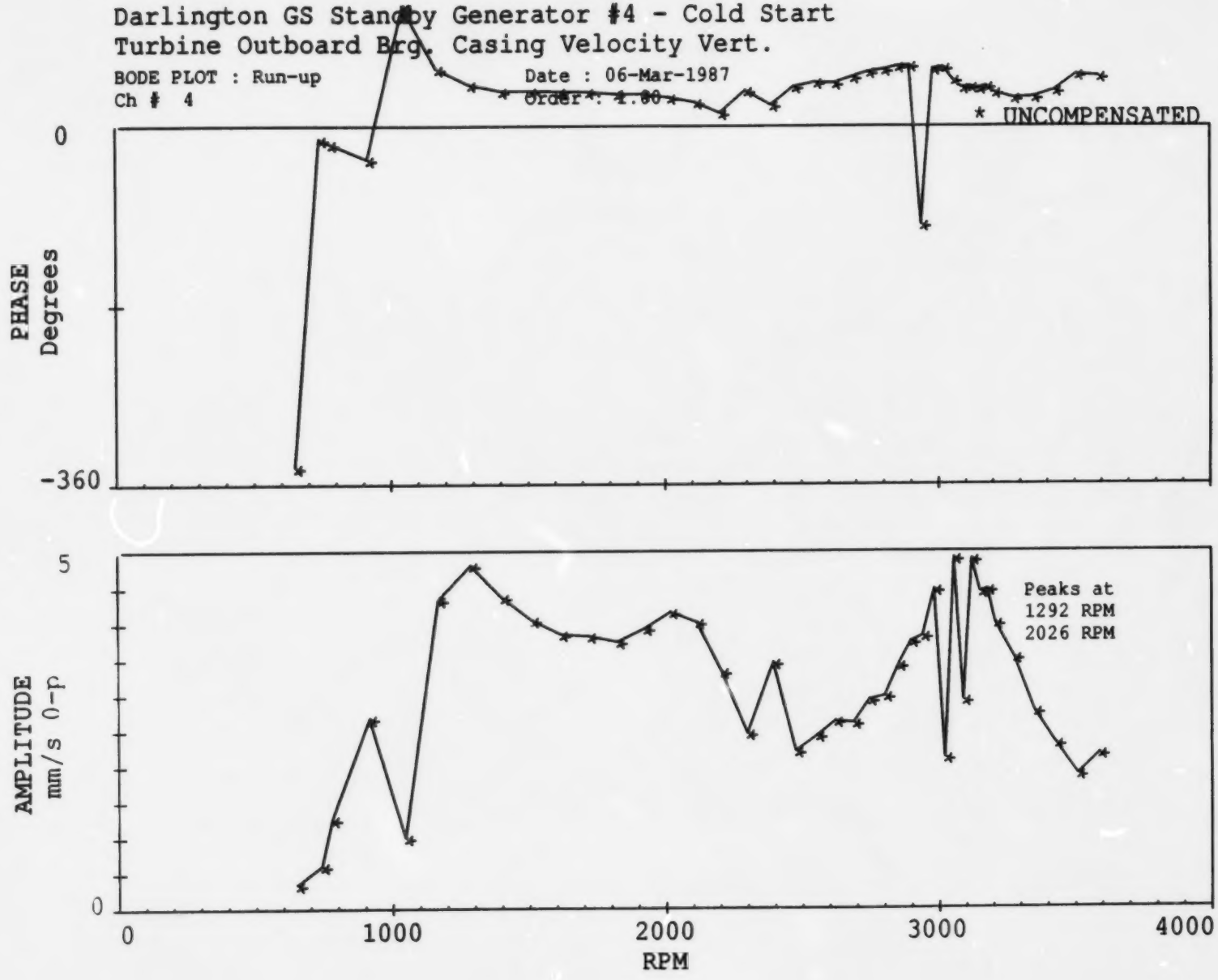
Darlington GS Standby Generator #4 - Cold Start
Turbine Outboard Brg. Casing Velocity Vert.
BODE PLOT : Run-up
Ch # 4
Date : 06-Mar-1987
Order : 1.00
* UNCOMPENSATED
PHASE
Degrees
0
-360
AMPLITUDE
mm/s 0-p
5
0
Peaks at
1292 RPM
2026 RPM
0
1000
2000
3000
4000
RPM

FIGURE 121

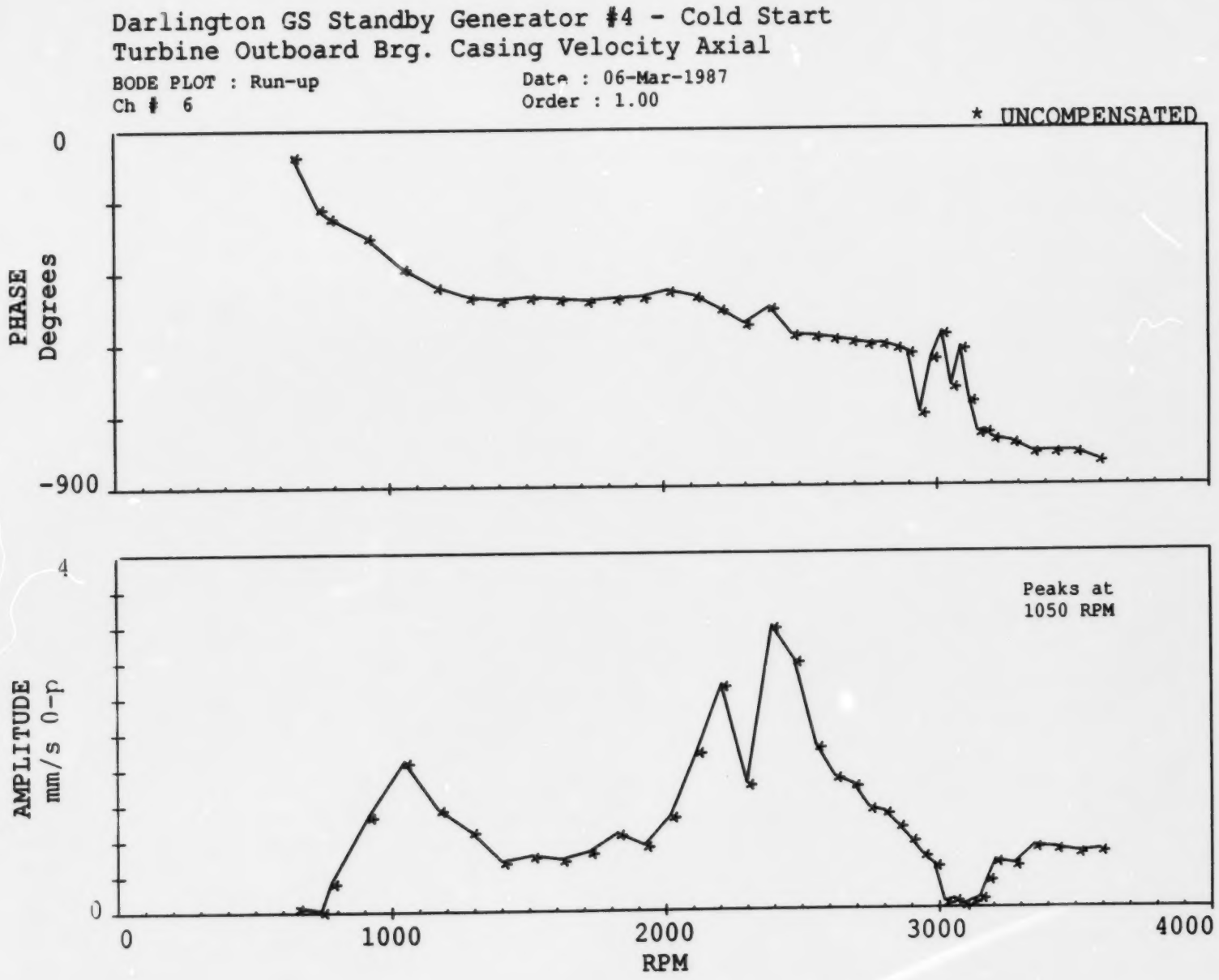
Darlington GS Standby Generator #4 - Cold Start
Turbine Outboard Brg. Casing Velocity Axial
BODE PLOT : Run-up
Ch # 6
Date : 06-Mar-1987
Order : 1.00
* UNCOMPENSATED
0
PHASE
Degrees
-900
4
AMPLITUDE
mm/s 0-p
0
Peaks at
1050 RPM
0
1000
2000
3000
4000
RPM

FIGURE 122

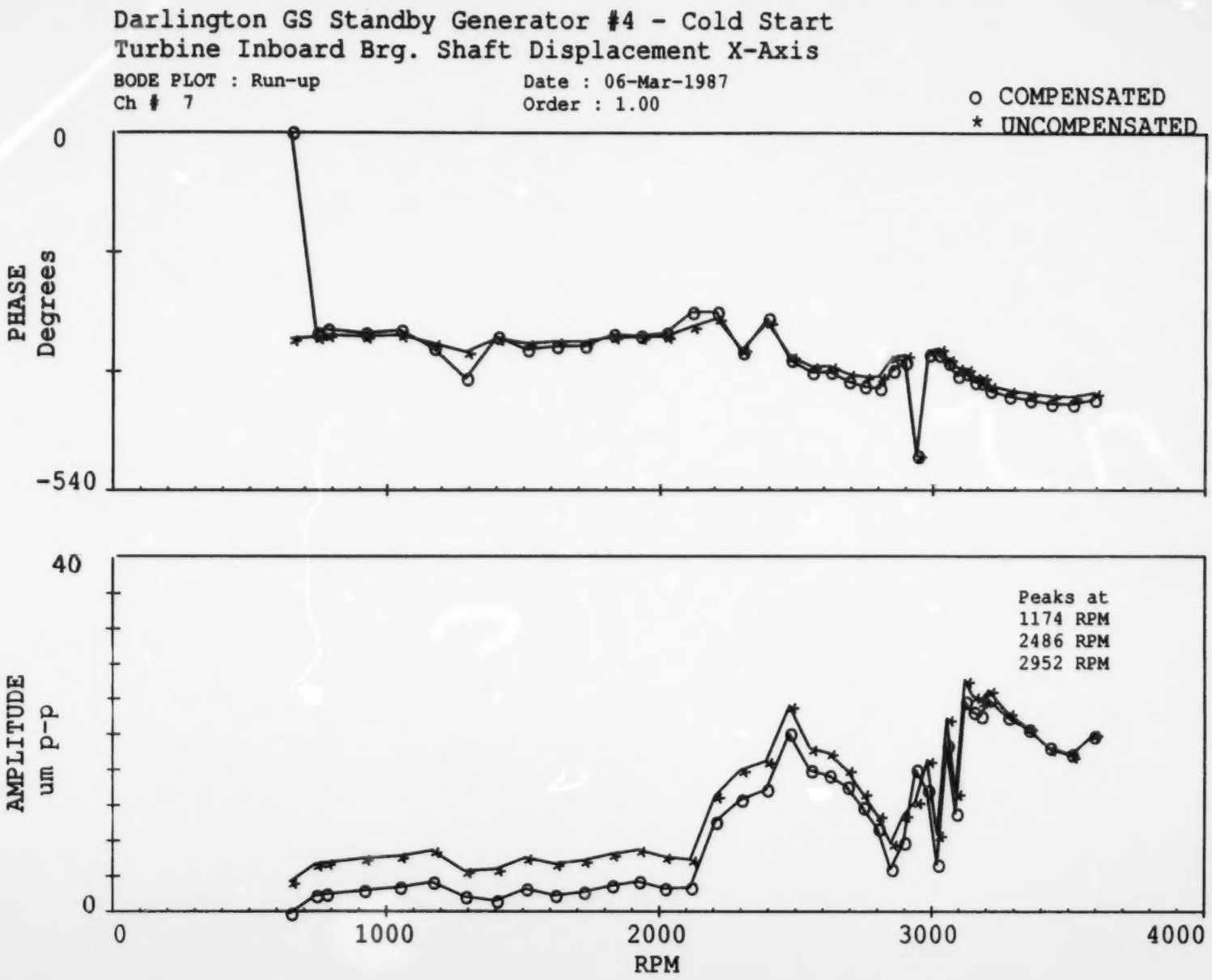

FIGURE 123

89-6

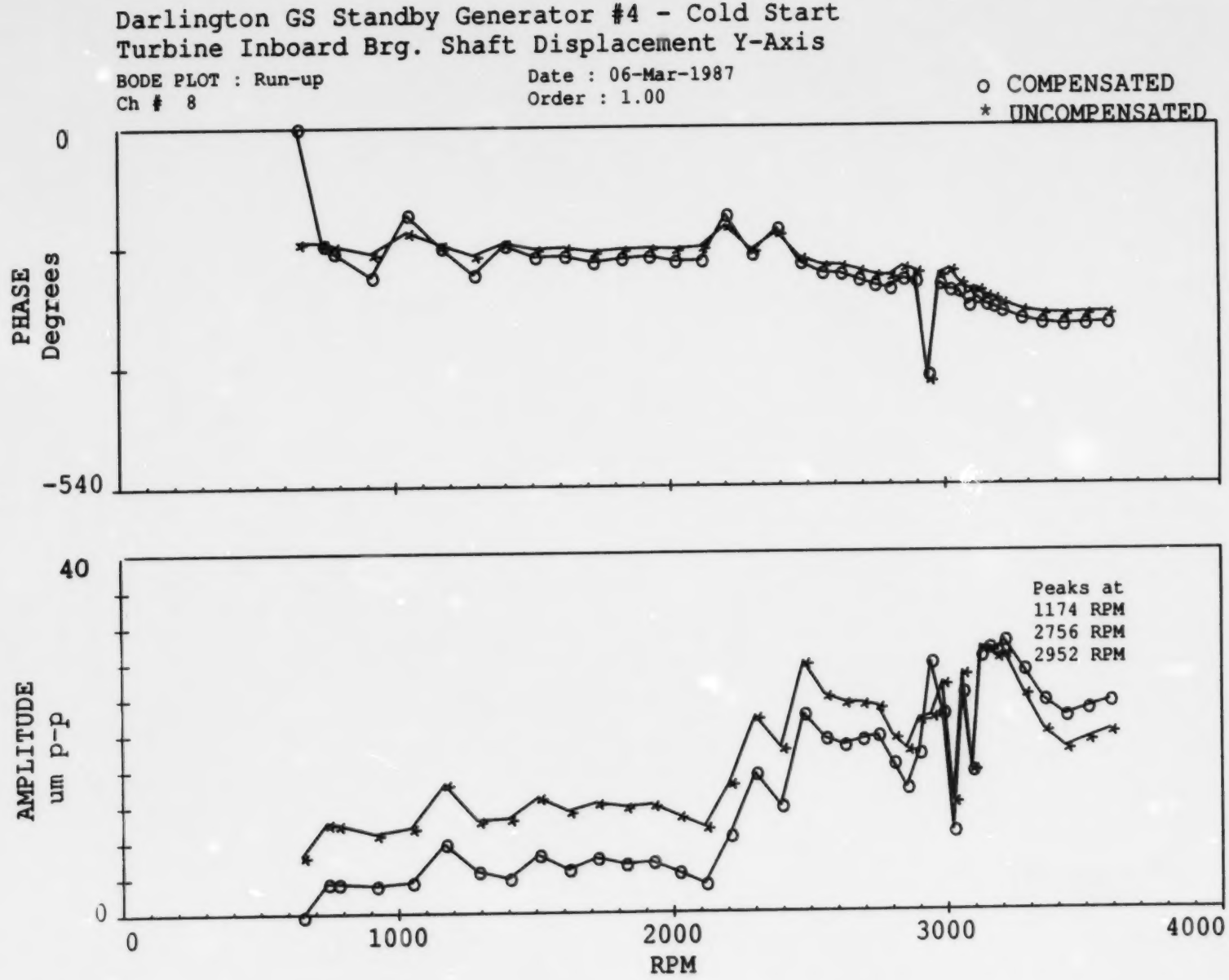
Darlington GS Standby Generator #4 - Cold Start
Turbine Inboard Brg. Shaft Displacement Y-Axis
BODE PLOT : Run-up
Ch # 8
Date : 06-Mar-1987
Order : 1.00
o COMPENSATED
* UNCOMPENSATED
0
PHASE
Degrees
-540
40
AMPLITUDE
um p-p
0
Peaks at
1174 RPM
2756 RPM
2952 RPM
0
1000
2000
3000
4000
RPM

FIGURE 124

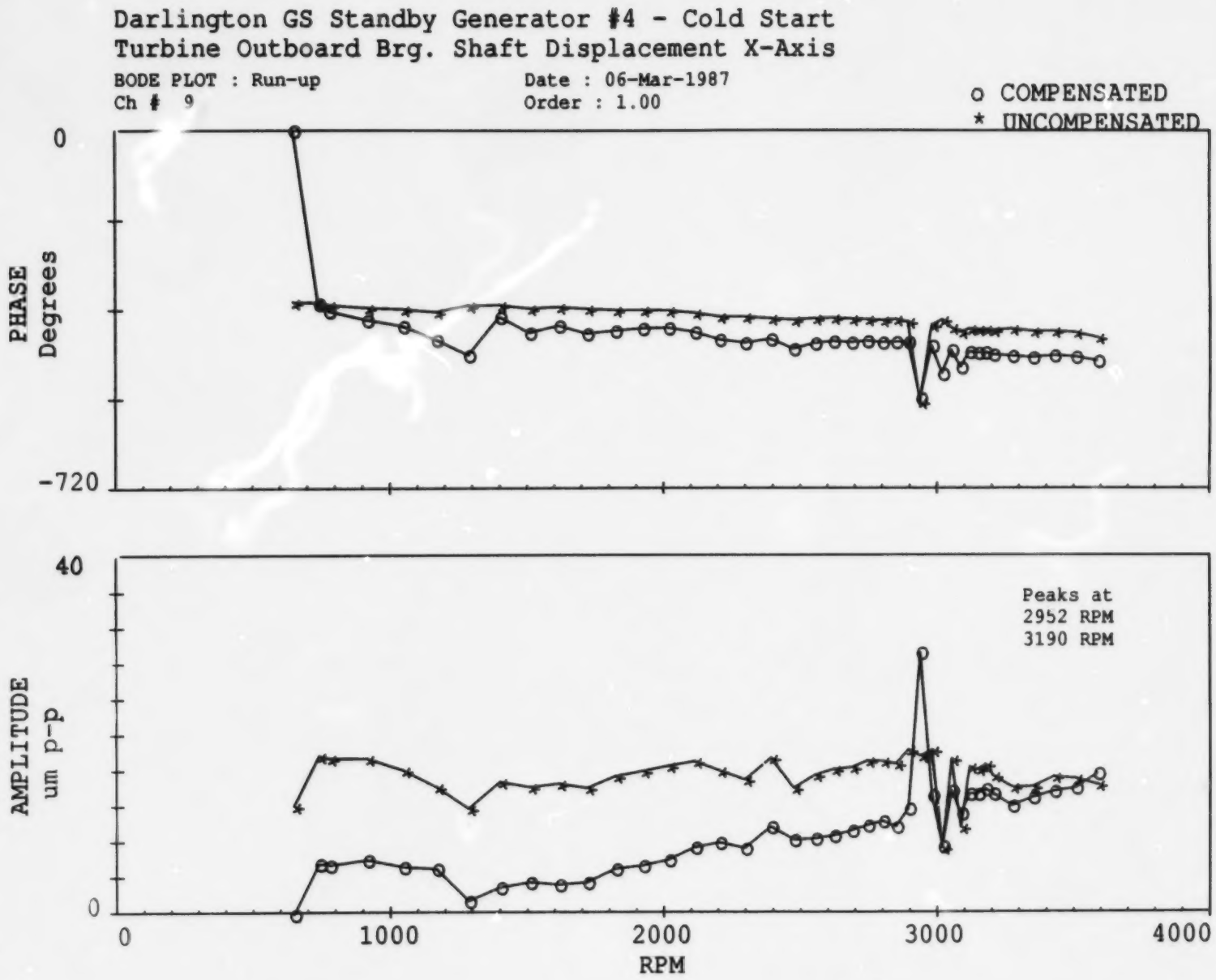

FIGURE 125

89-6

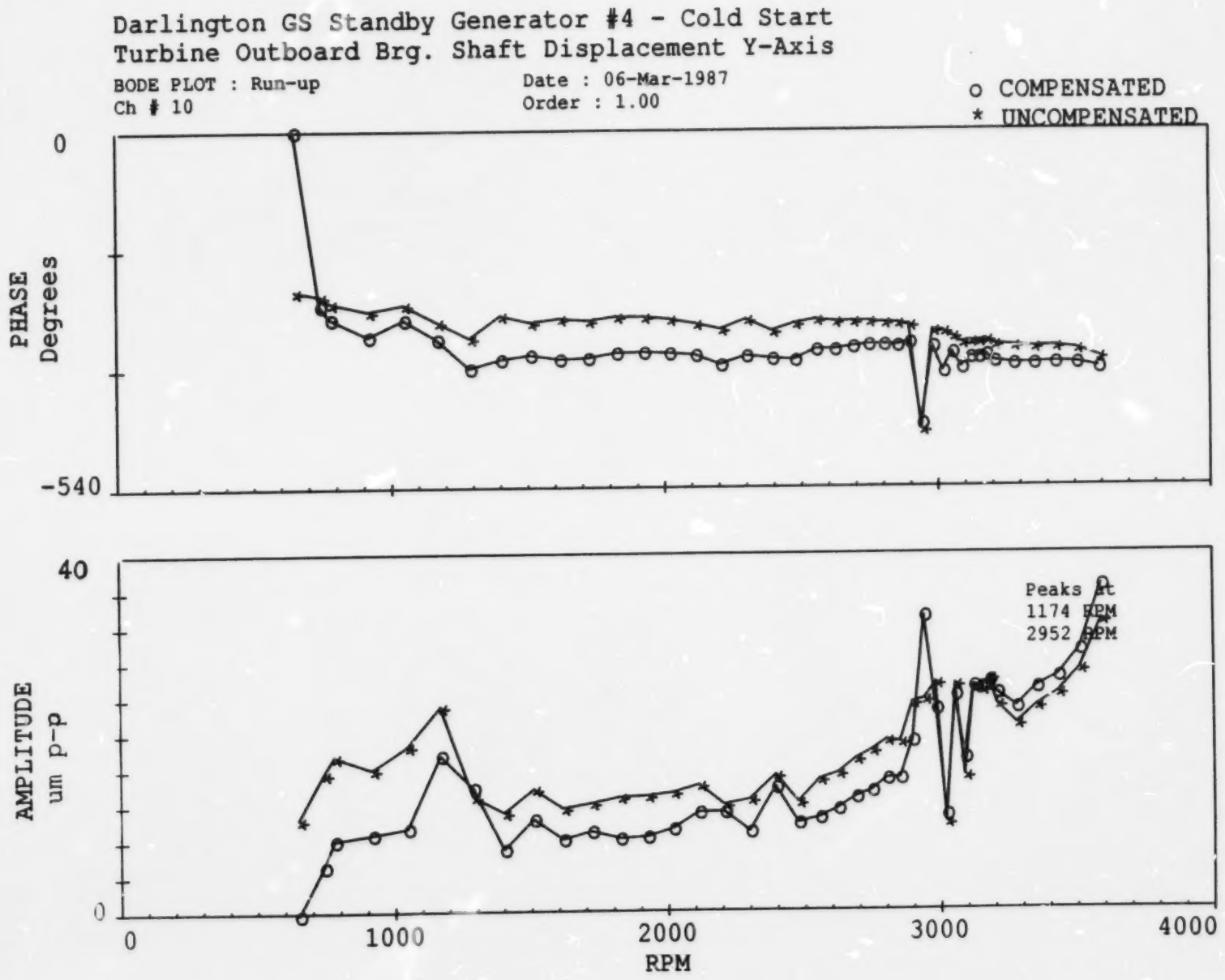
Darlington GS Standby Generator #4 - Cold Start
Turbine Outboard Brg. Shaft Displacement Y-Axis
BODE PLOT : Run-up
Ch # 10
Date : 06-Mar-1987
Order : 1.00
o COMPENSATED
* UNCOMPENSATED
PHASE
Degrees
0
-540
AMPLITUDE
um p-p
40
0
Peaks At
1174 RPM
2952 RPM
0
1000
2000
3000
4000
RPM

FIGURE 126

Darlington GS Standby Generator #4
AC Generator Outboard Brg. Casing Velocity X-Axis

BODE PLOT : Run-up
Ch # 2

Date : 10-Mar-1987
Order : 1.00

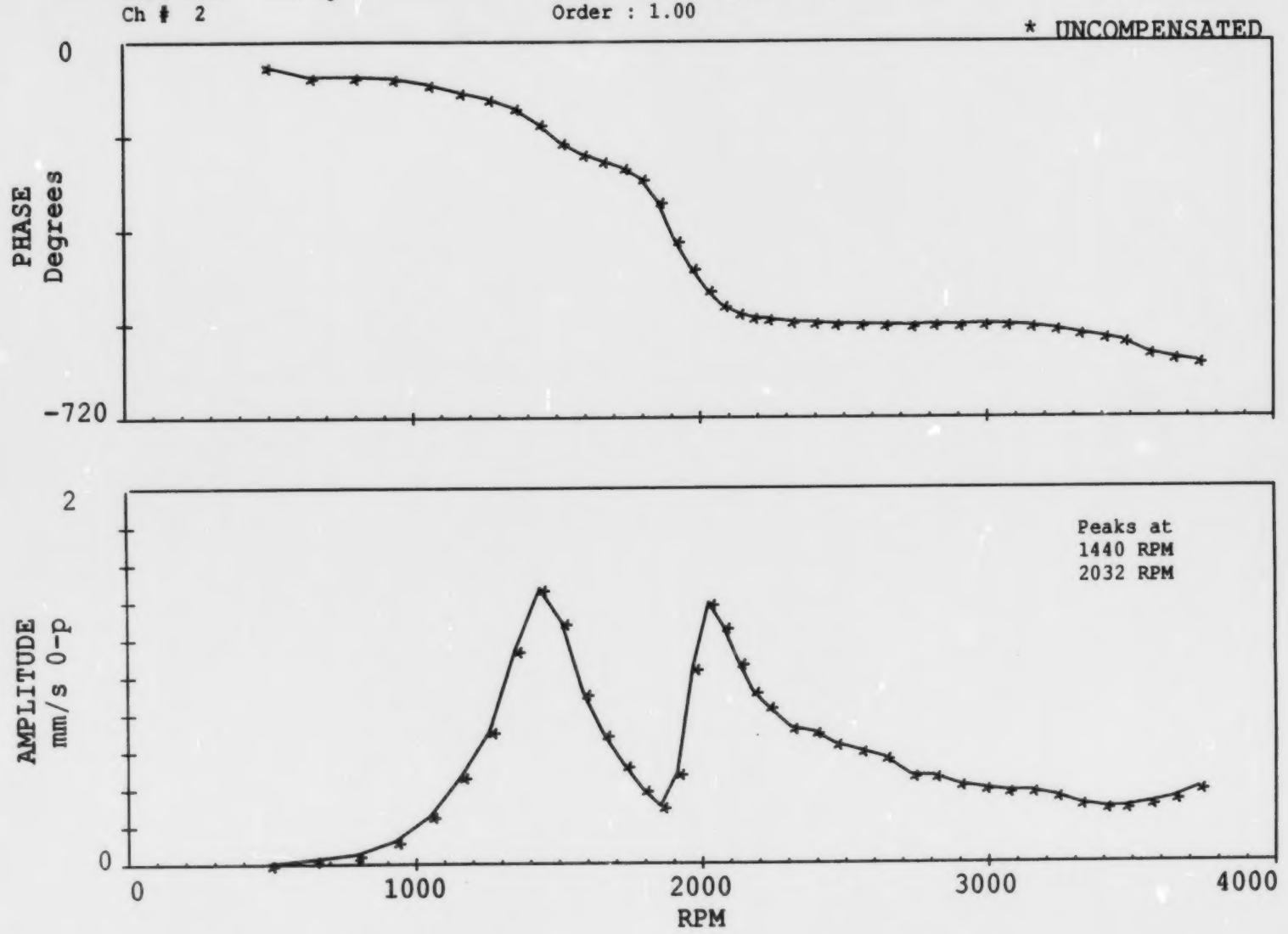

FIGURE 127

89-6

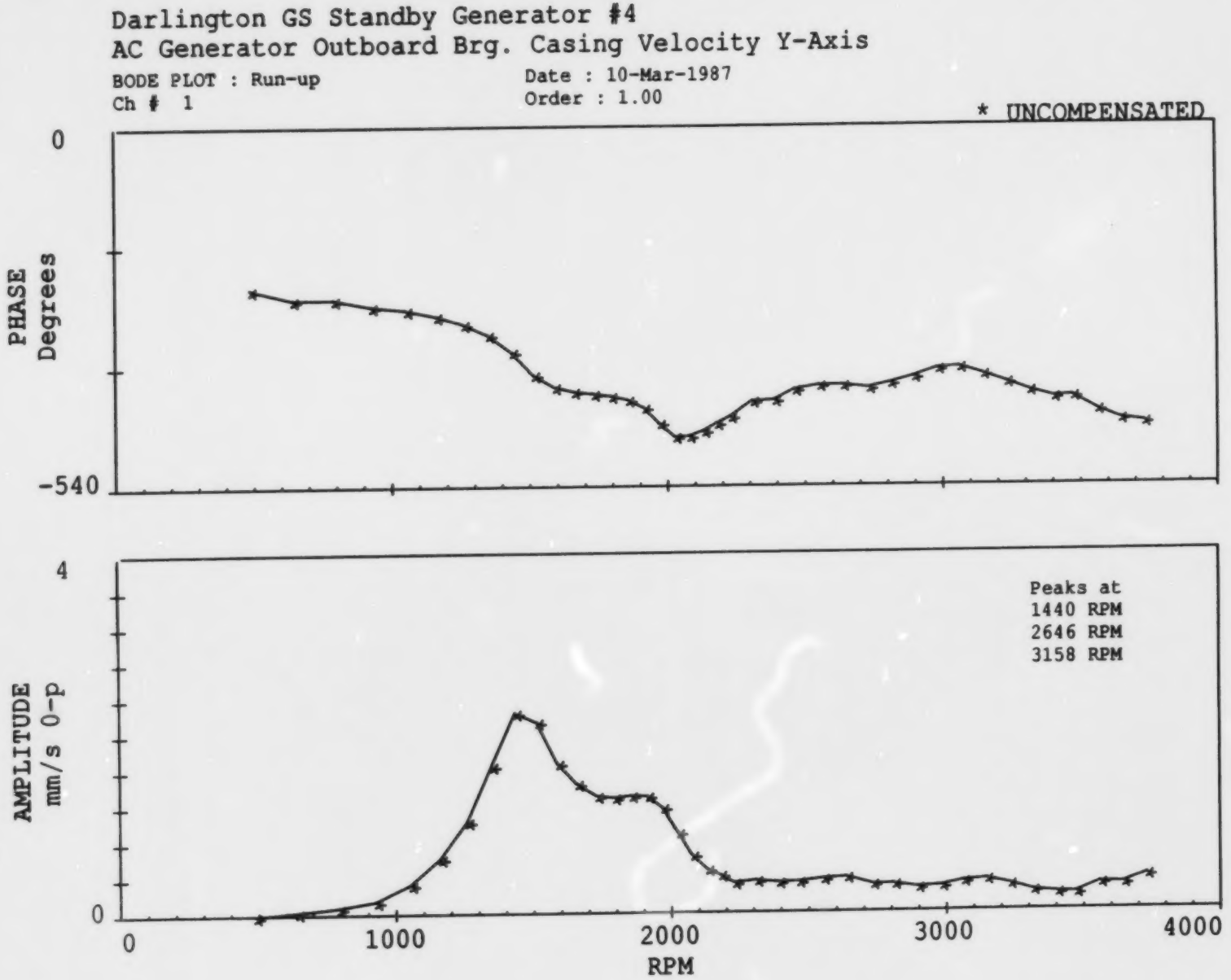
Darlington GS Standby Generator #4
AC Generator Outboard Brg. Casing Velocity Y-Axis
BODE PLOT : Run-up
Ch # 1
Date : 10-Mar-1987
Order : 1.00
* UNCOMPENSATED
0
PHASE
Degrees
-540
4
AMPLITUDE
mm/s 0-p
0
Peaks at
1440 RPM
2646 RPM
3158 RPM
0
1000
2000
3000
4000
RPM

FIGURE 128

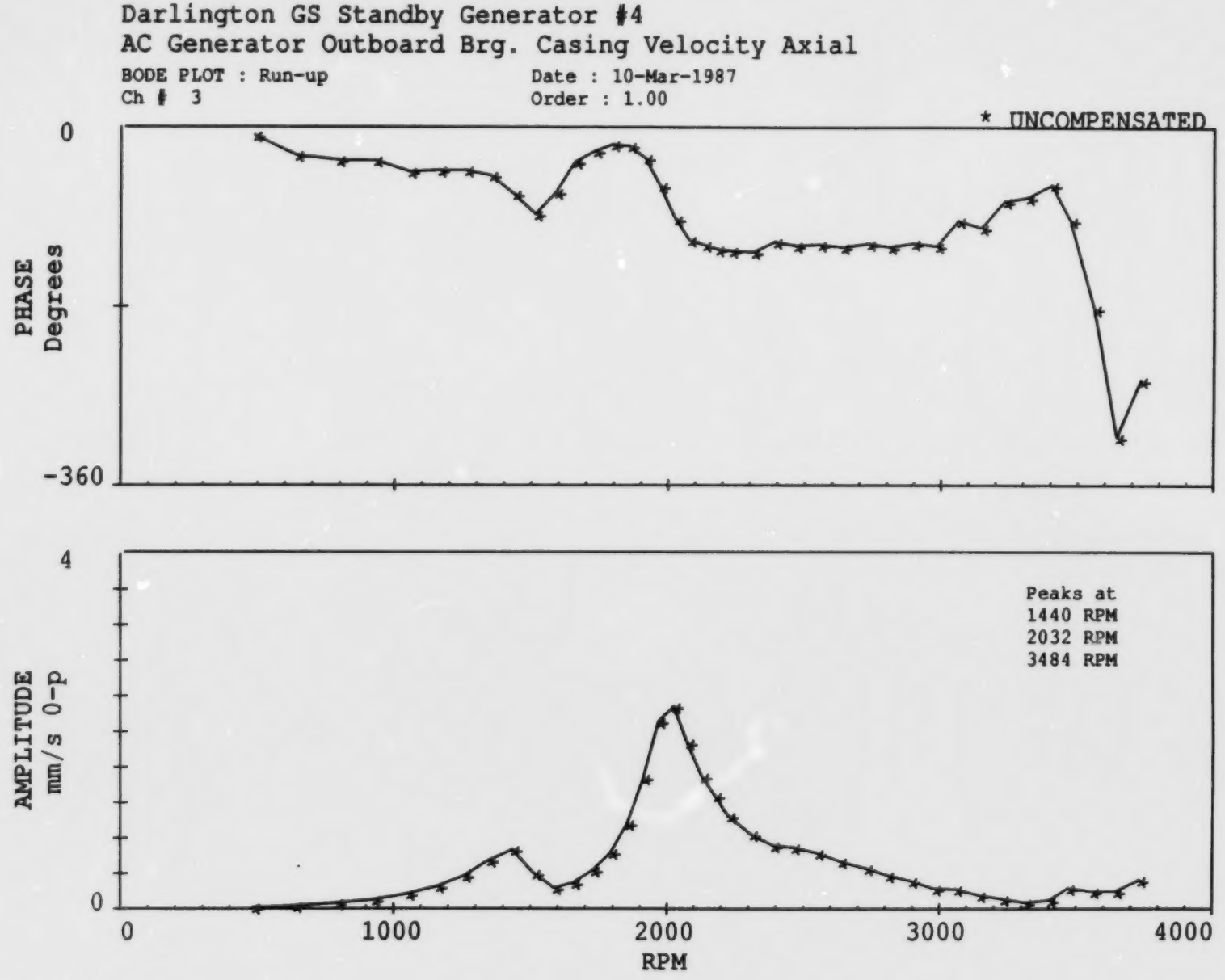
Darlington GS Standby Generator #4
AC Generator Outboard Brg. Casing Velocity Axial
BODE PLOT : Run-up
Ch # 3
Date : 10-Mar-1987
Order : 1.00
* UNCOMPENSATED
0
PHASE
Degrees
-360
4
AMPLITUDE
mm/s 0-p
0
Peaks at
1440 RPM
2032 RPM
3484 RPM
0
1000
2000
3000
4000
RPM

FIGURE 129

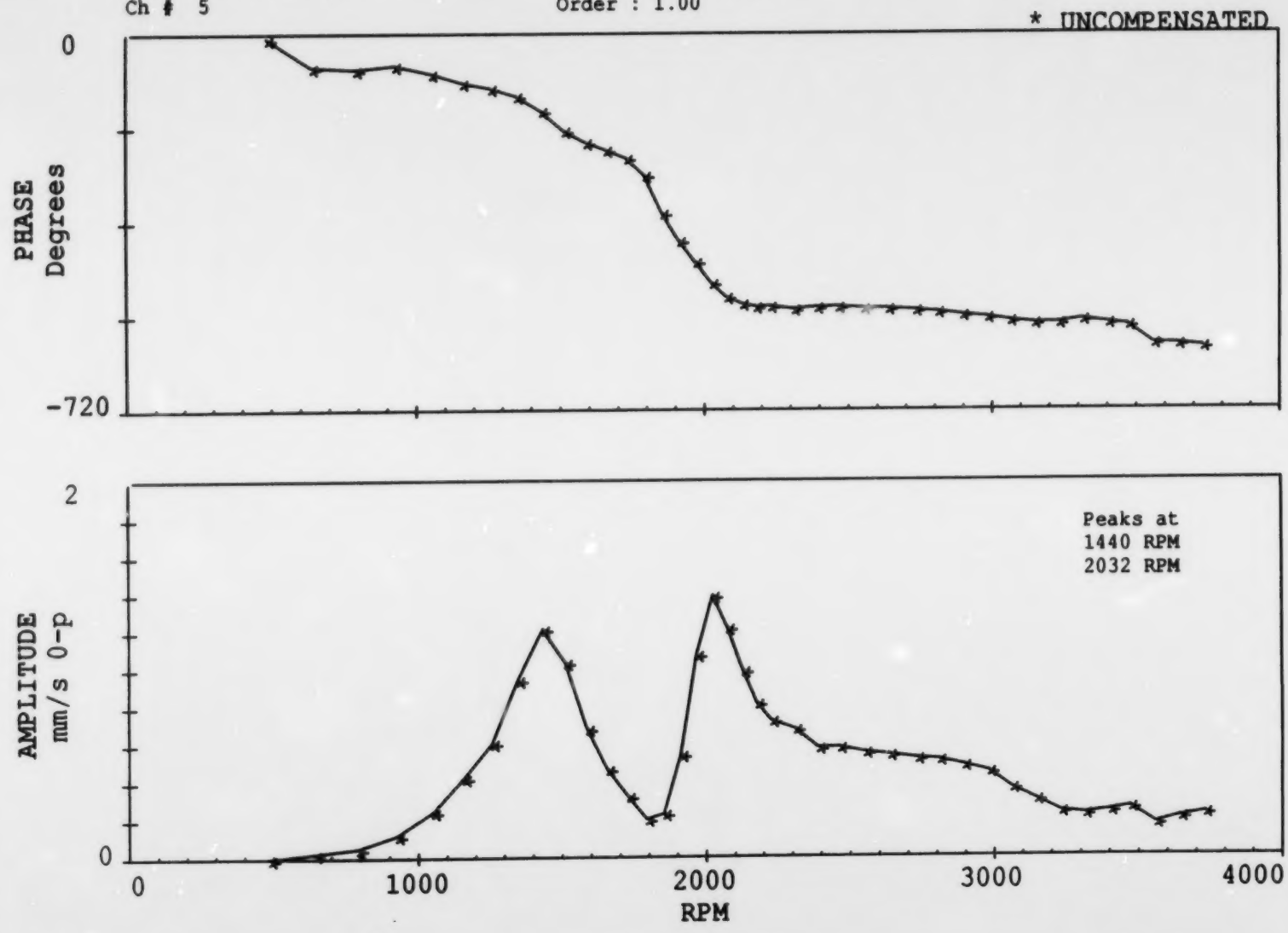
Darlington GS Standby Generator #4
AC Generator Inboard Brg. Casing Velocity X-Axis
BODE PLOT : Run-up
Ch # 5
Date : 10-Mar-1987
Order : 1.00
* UNCOMPENSATED
0
PHASE
Degrees
-720
2
AMPLITUDE
mm/s 0-p
0
Peaks at
1440 RPM
2032 RPM
0
1000
2000
3000
4000
RPM

FIGURE 130

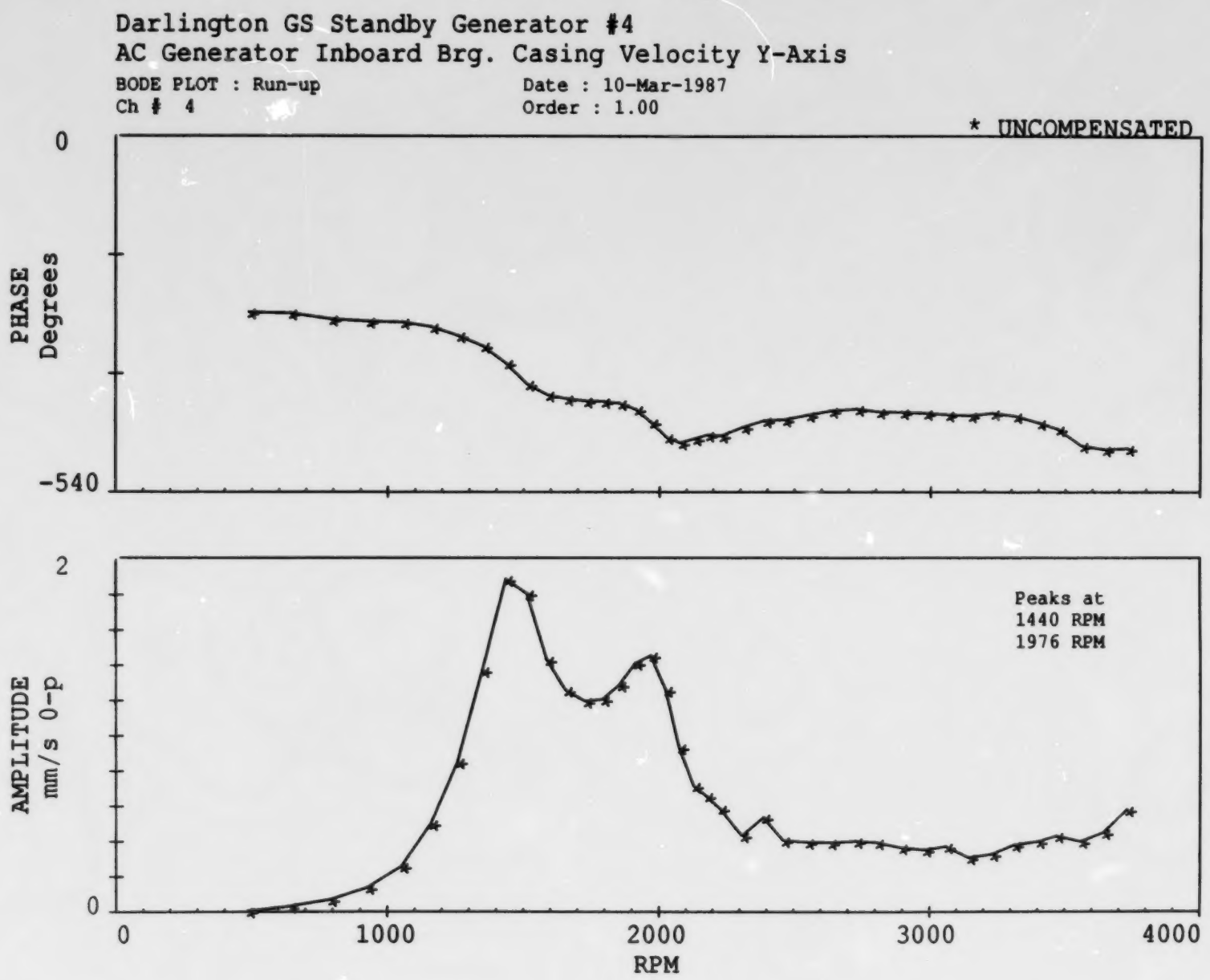
Darlington GS Standby Generator #4
AC Generator Inboard Brg. Casing Velocity Y-Axis
BODE PLOT : Run-up
Ch # 4
Date : 10-Mar-1987
Order : 1.00
* UNCOMPENSATED
0
PHASE
Degrees
-540
2
AMPLITUDE
mm/s 0-p
0
Peaks at
1440 RPM
1976 RPM
0
1000
2000
3000
4000
RPM

FIGURE 131

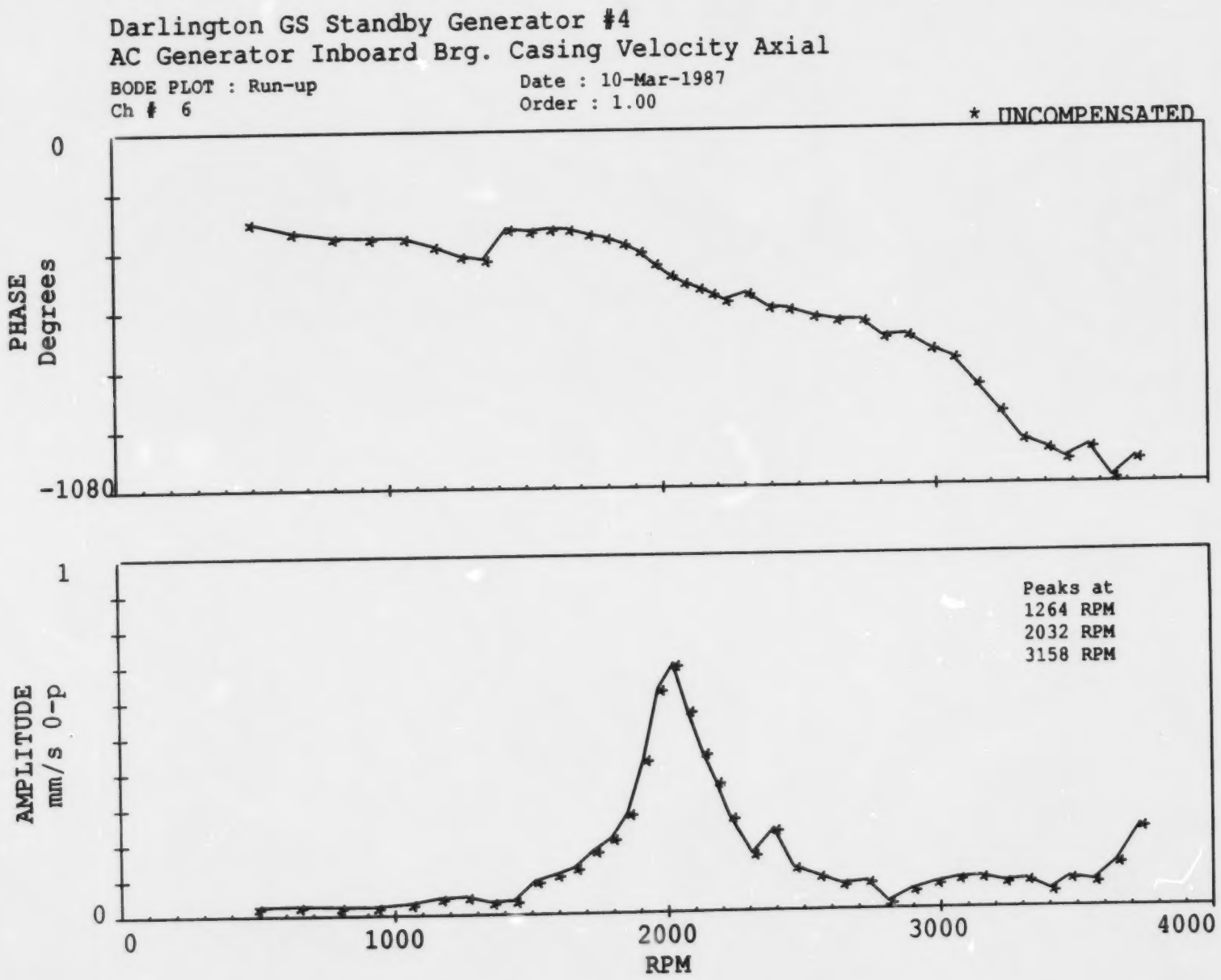

FIGURE 132

89-6

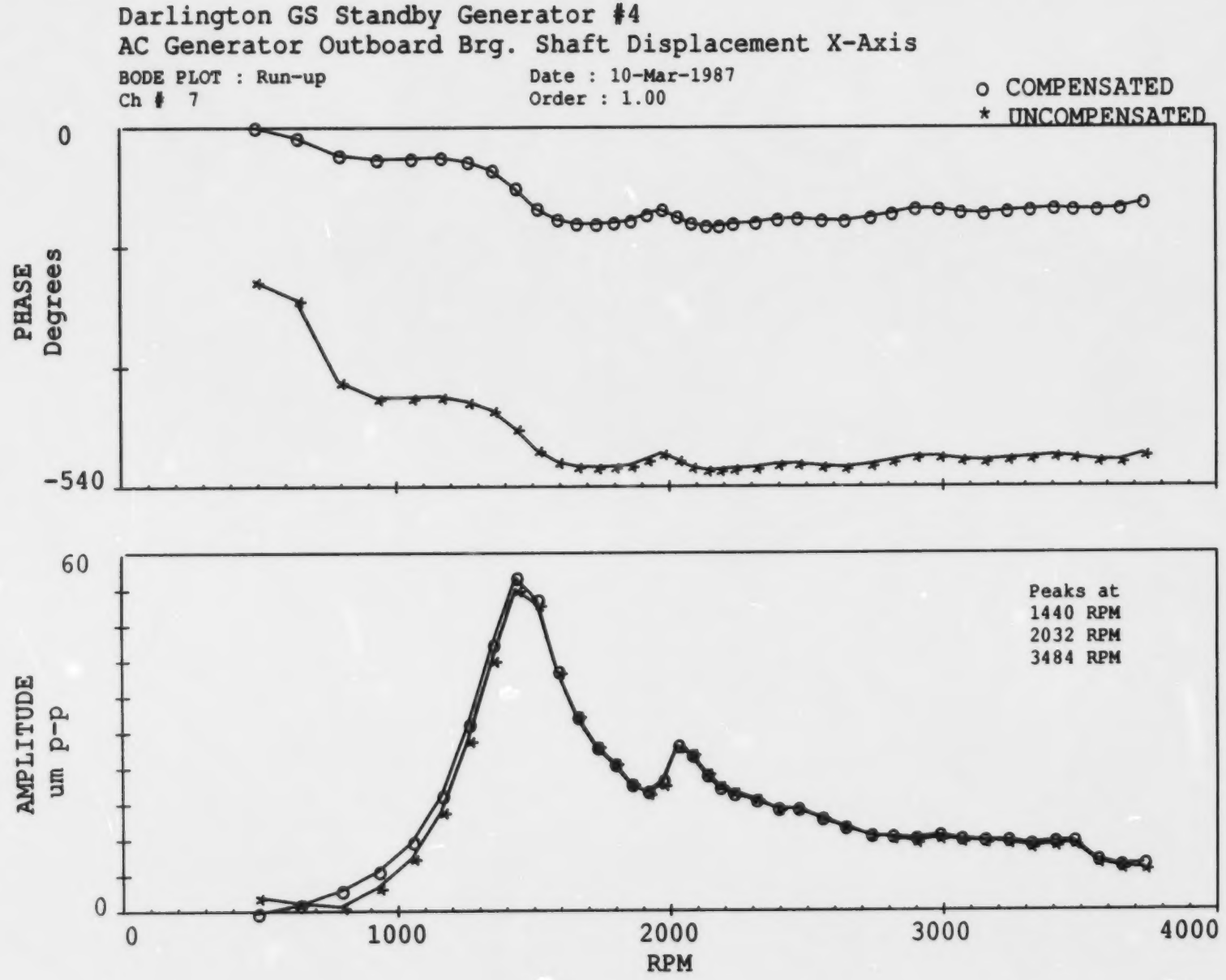
Darlington GS Standby Generator #4
AC Generator Outboard Brg. Shaft Displacement X-Axis
BODE PLOT : Run-up
Ch # 7
Date : 10-Mar-1987
Order : 1.00
o COMPENSATED
* UNCOMPENSATED
0
-540
PHASE
Degrees
60
0
AMPLITUDE
um p-p
Peaks at
1440 RPM
2032 RPM
3484 RPM
0
1000
2000
3000
4000
RPM

FIGURE 133

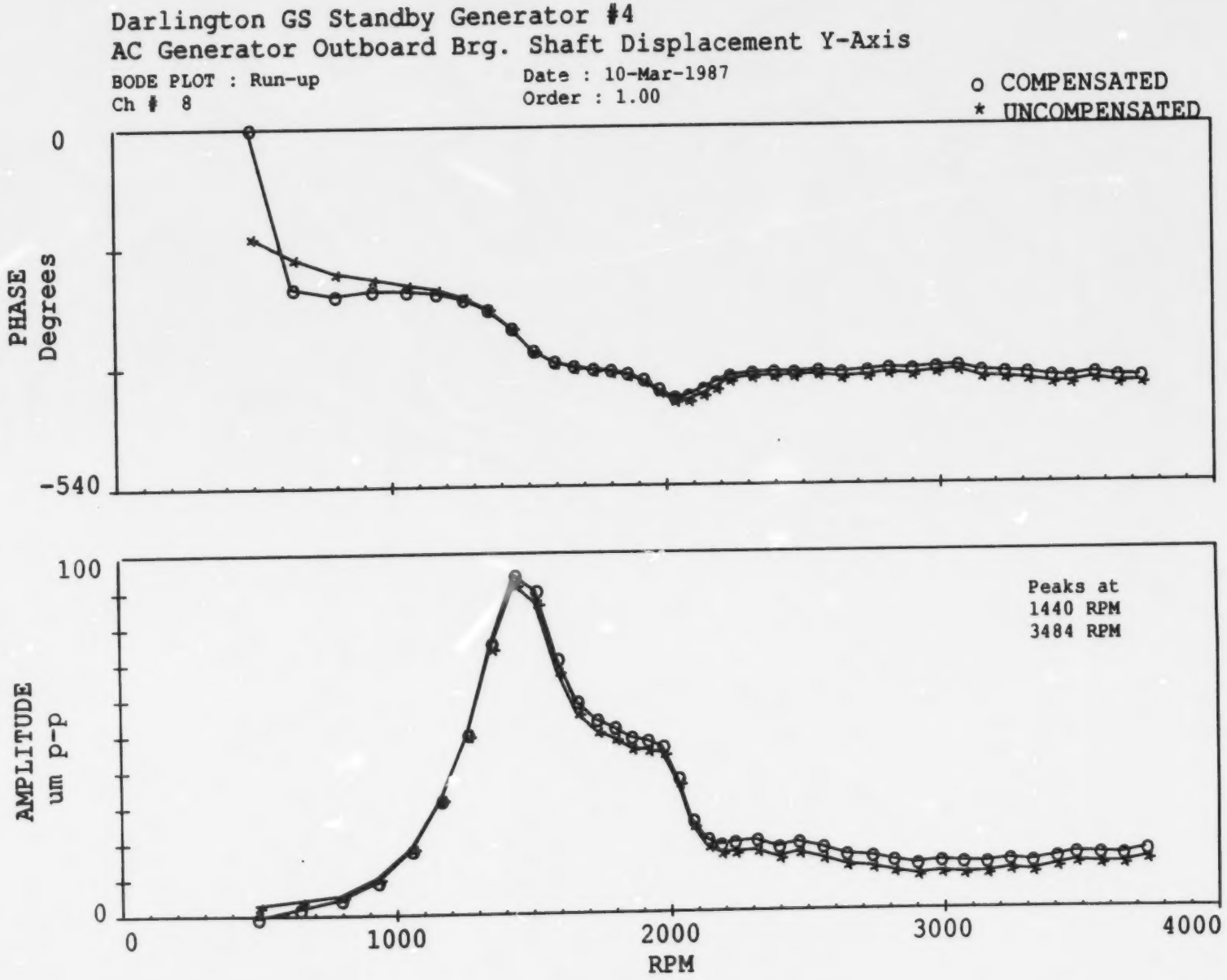
Darlington GS Standby Generator #4
AC Generator Outboard Brg. Shaft Displacement Y-Axis
BODE PLOT : Run-up
Ch # 8
Date : 10-Mar-1987
Order : 1.00
o COMPENSATED
* UNCOMPENSATED
0
-540
PHASE
Degrees
100
0
AMPLITUDE
um p-p
Peaks at
1440 RPM
3484 RPM
0
1000
2000
3000
4000
RPM

FIGURE 134

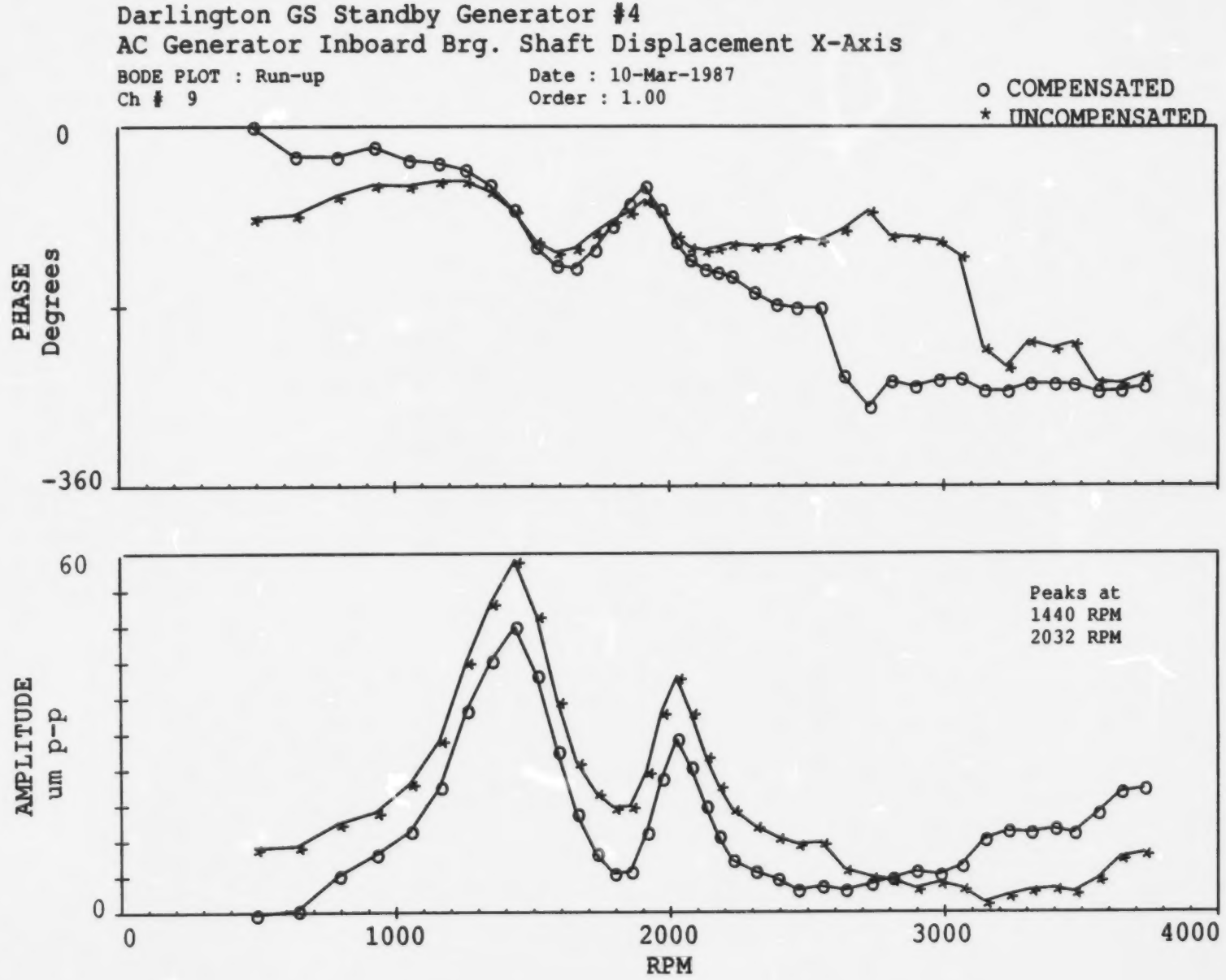

FIGURE 135

89-6

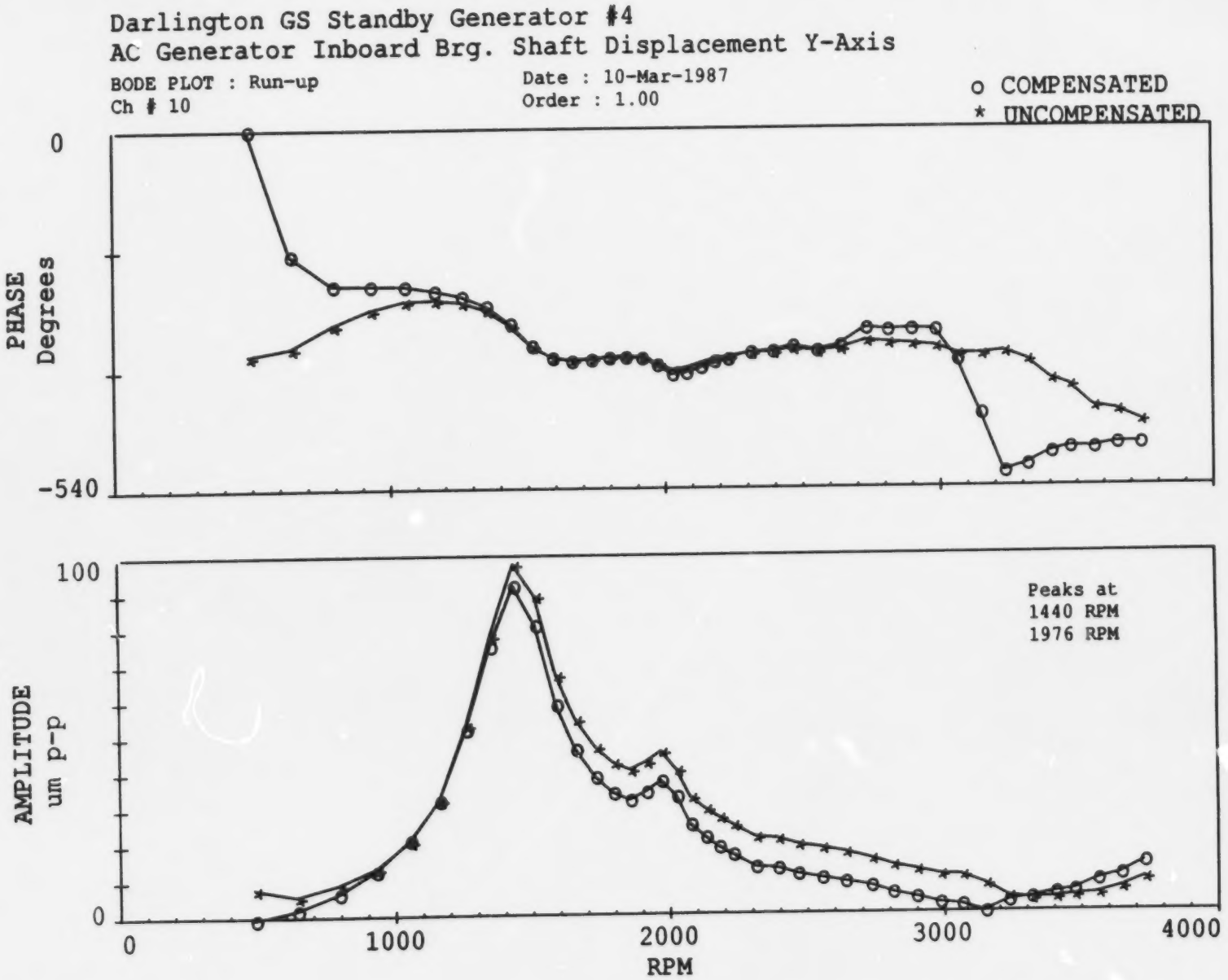

FIGURE 136

89-6

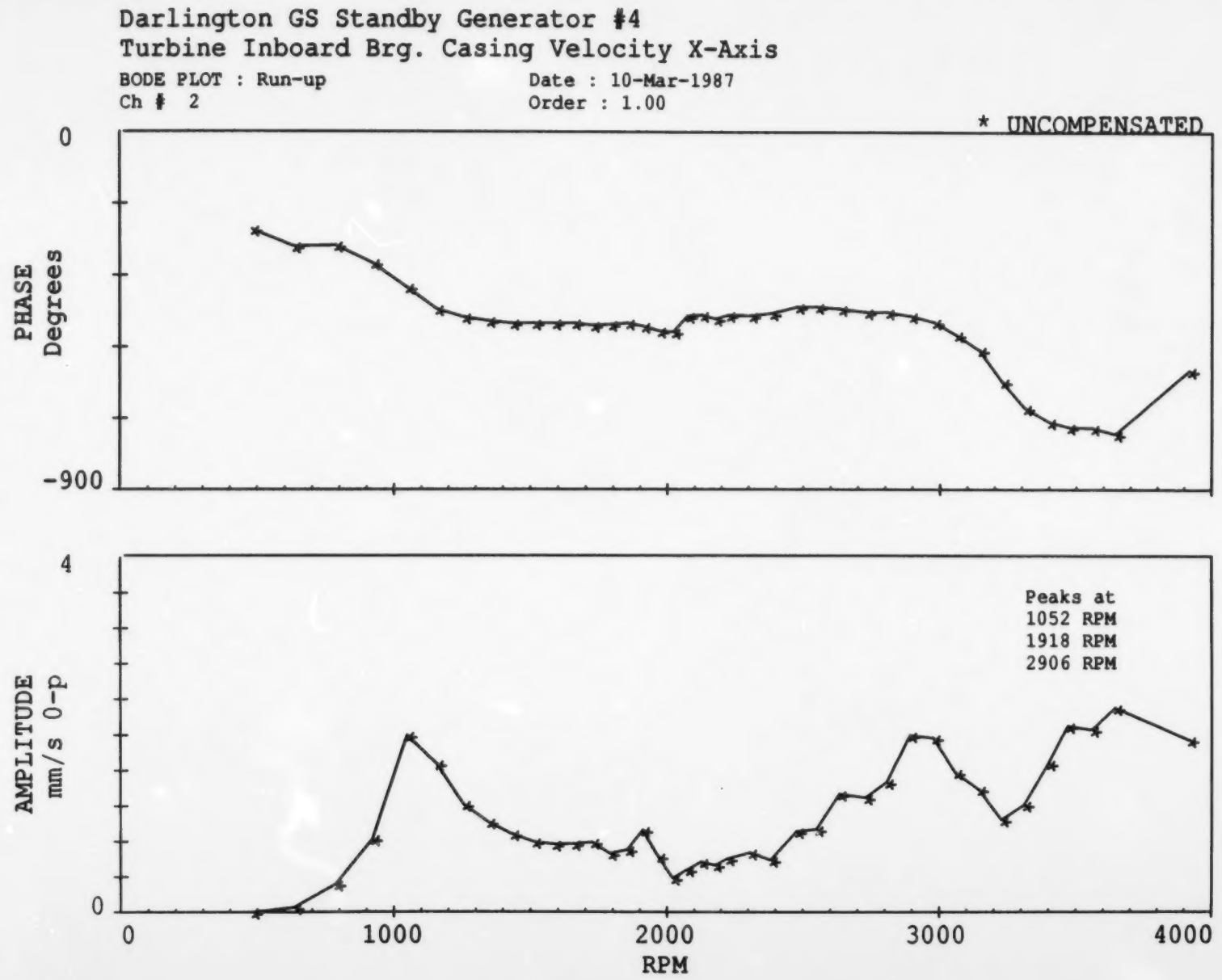
Darlington GS Standby Generator #4
Turbine Inboard Brg. Casing Velocity X-Axis
BODE PLOT : Run-up
Ch # 2
Date : 10-Mar-1987
Order : 1.00
* UNCOMPENSATED
0
-900
PHASE
Degrees
4
0
AMPLITUDE
mm/s 0-p
Peaks at
1052 RPM
1918 RPM
2906 RPM
0
1000
2000
3000
4000
RPM

FIGURE 137

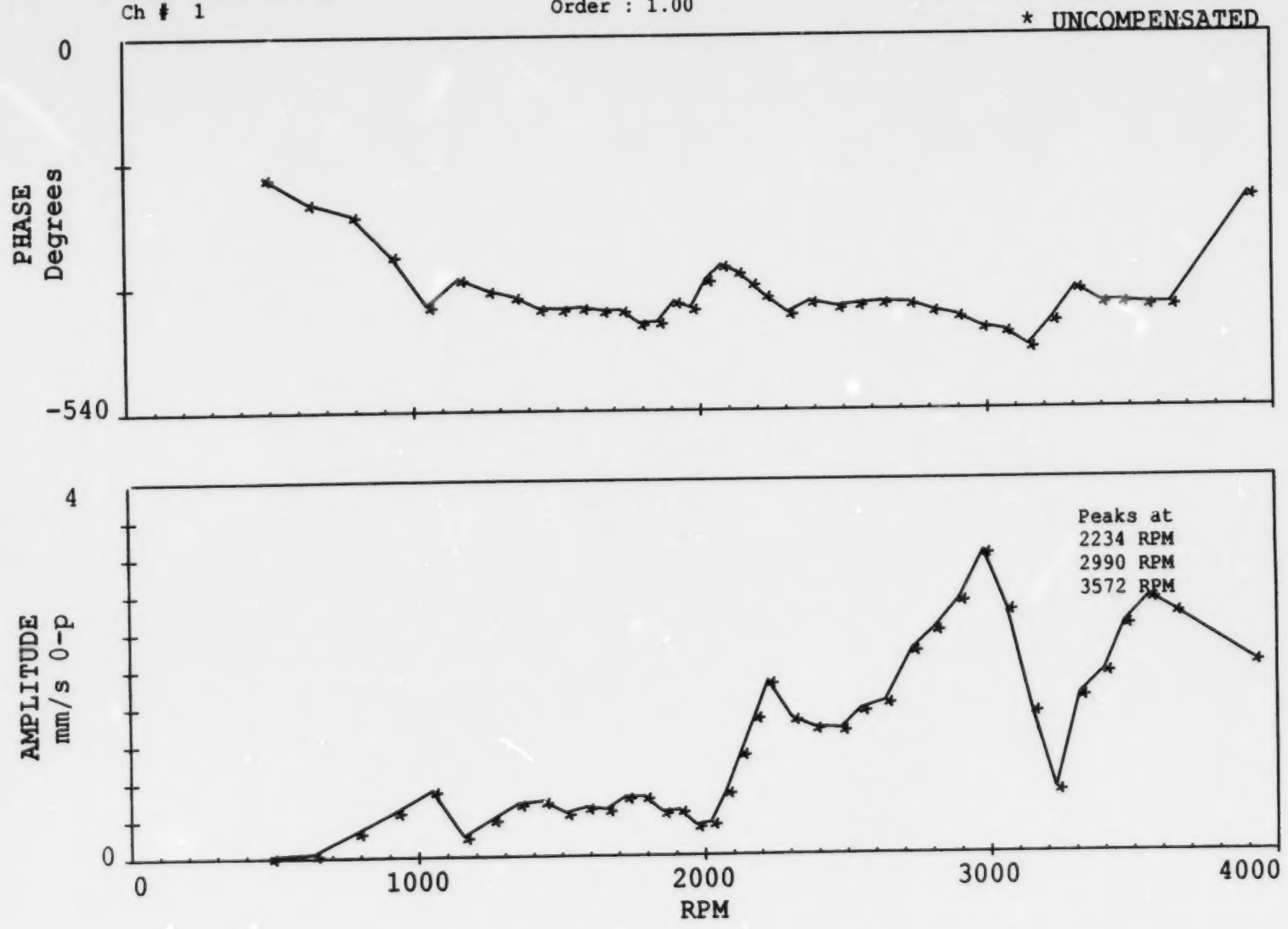
Darlington GS Standby Generator #4
Turbine Inboard Brg. Casing Velocity Y-Axis
BODE PLOT : Run-up
Ch # 1
Date : 10-Mar-1987
Order : 1.00
* UNCOMPENSATED
0
PHASE
Degrees
-540
4
AMPLITUDE
mm/s 0-p
0
Peaks at
2234 RPM
2990 RPM
3572 RPM
0
1000
2000
3000
4000
RPM

FIGURE 138

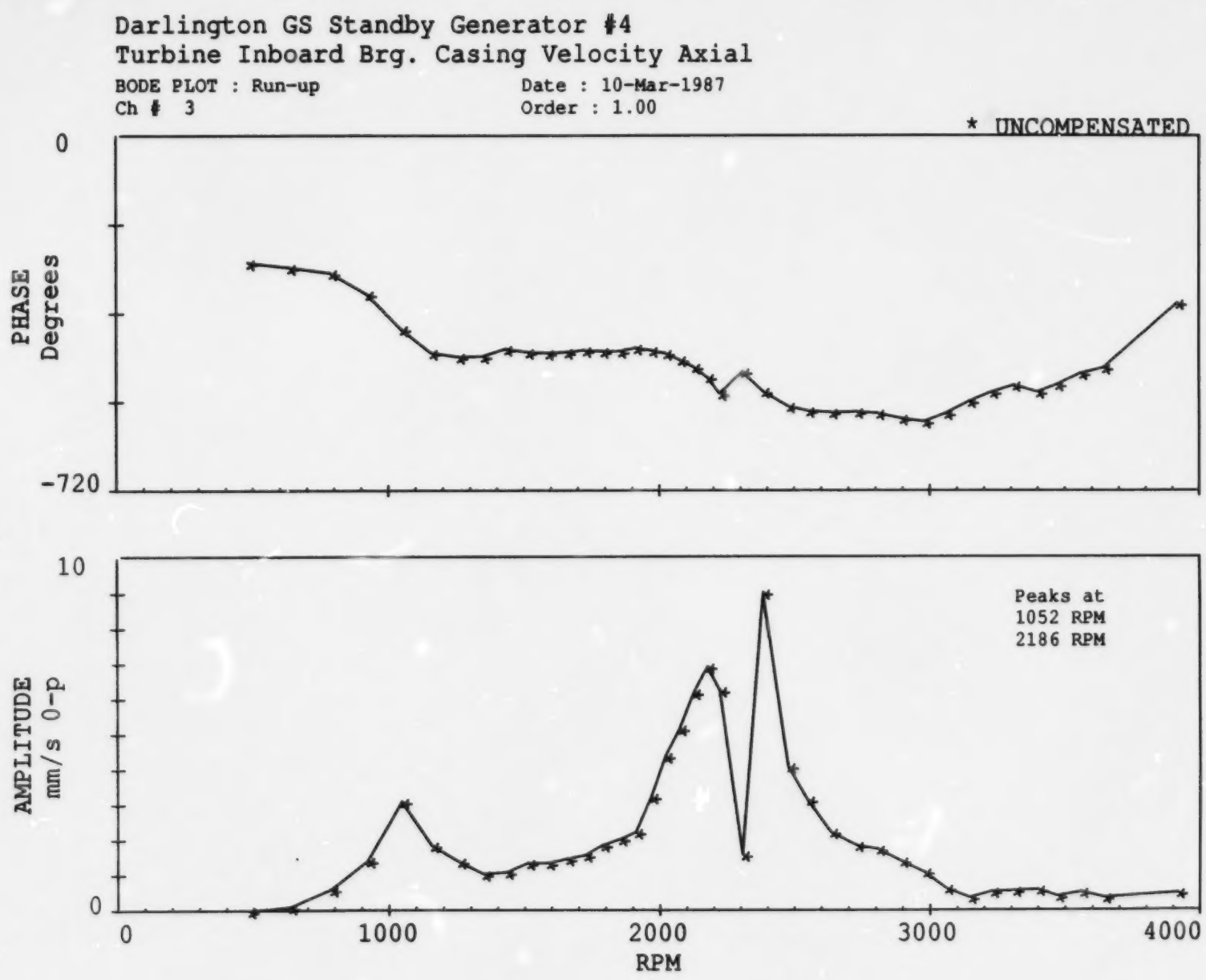
Darlington GS Standby Generator #4
Turbine Inboard Brg. Casing Velocity Axial
BODE PLOT : Run-up
Ch # 3
Date : 10-Mar-1987
Order : 1.00
* UNCOMPENSATED
0
PHASE
Degrees
-720
10
AMPLITUDE
mm/s 0-p
0
Peaks at
1052 RPM
2186 RPM
0
1000
2000
3000
4000
RPM

FIGURE 139

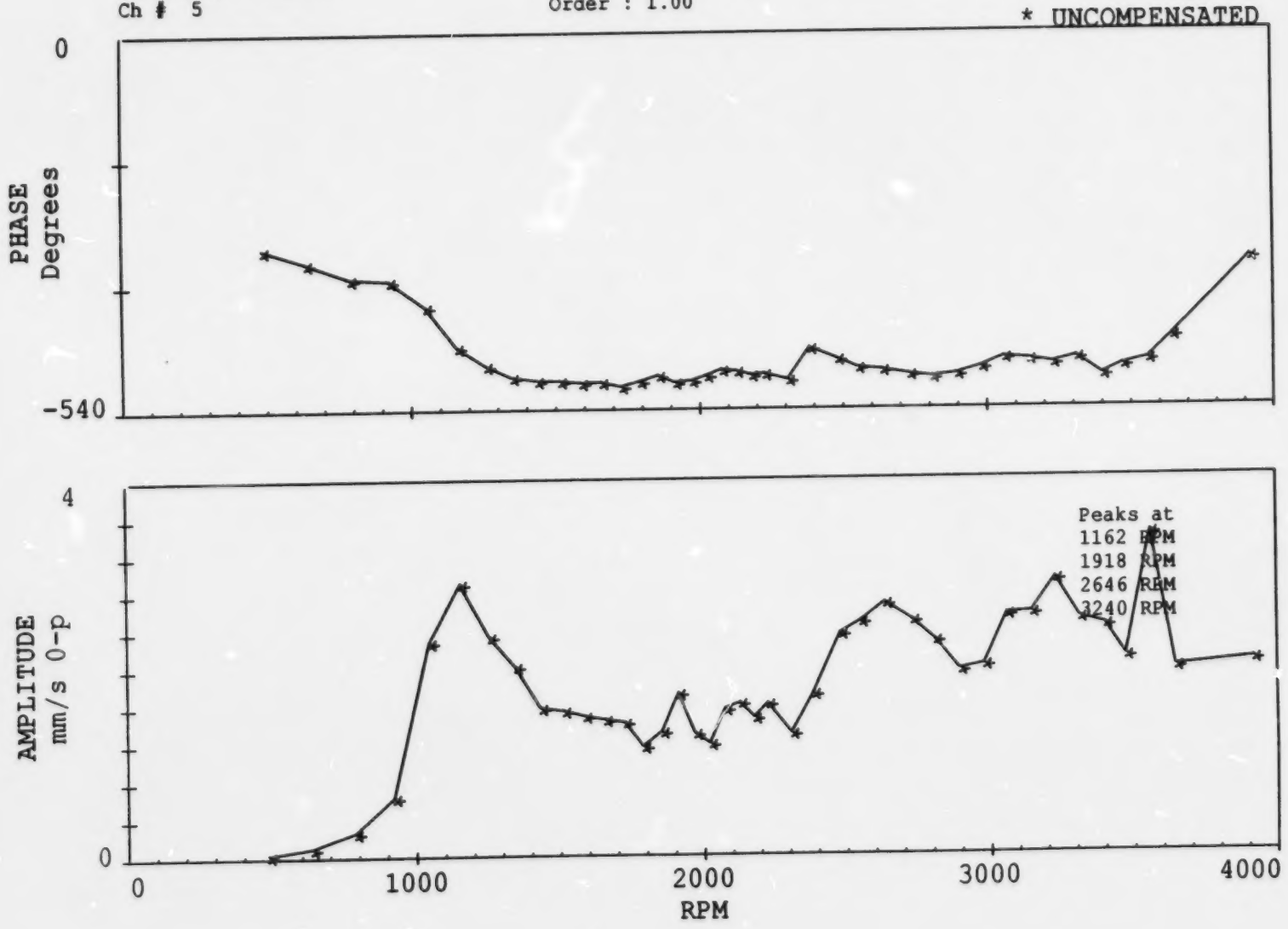

FIGURE 140

89-6

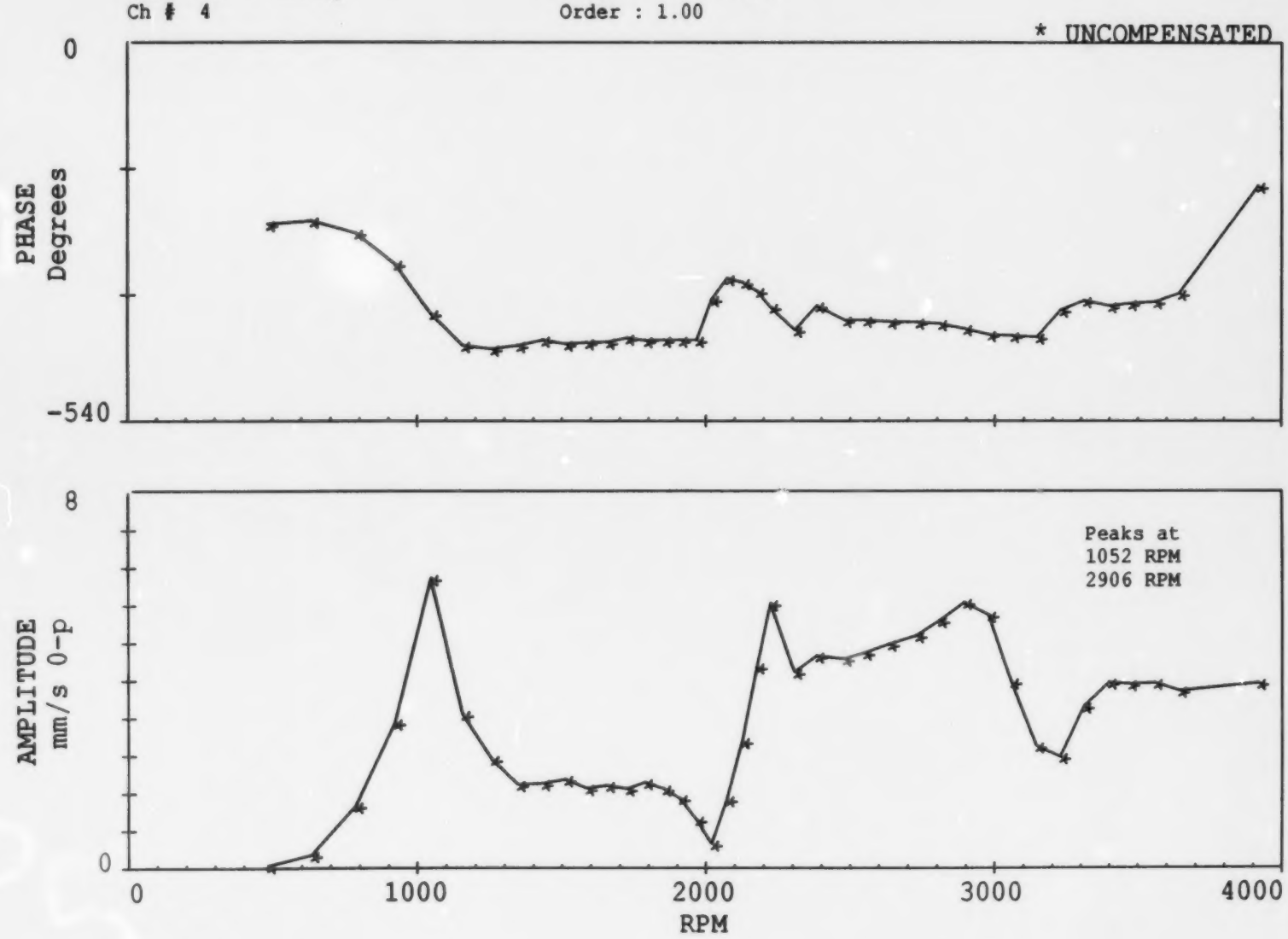
Darlington GS Standby Generator #4
Turbine Outboard Brg. Casing Velocity Vert.
BODE PLOT : Run-up
Ch # 4
Date : 10-Mar-1987
Order : 1.00
* UNCOMPENSATED
0
PHASE
Degrees
-540
8
AMPLITUDE
mm/s 0-p
0
Peaks at
1052 RPM
2906 RPM
0
1000
2000
3000
4000
RPM

FIGURE 141

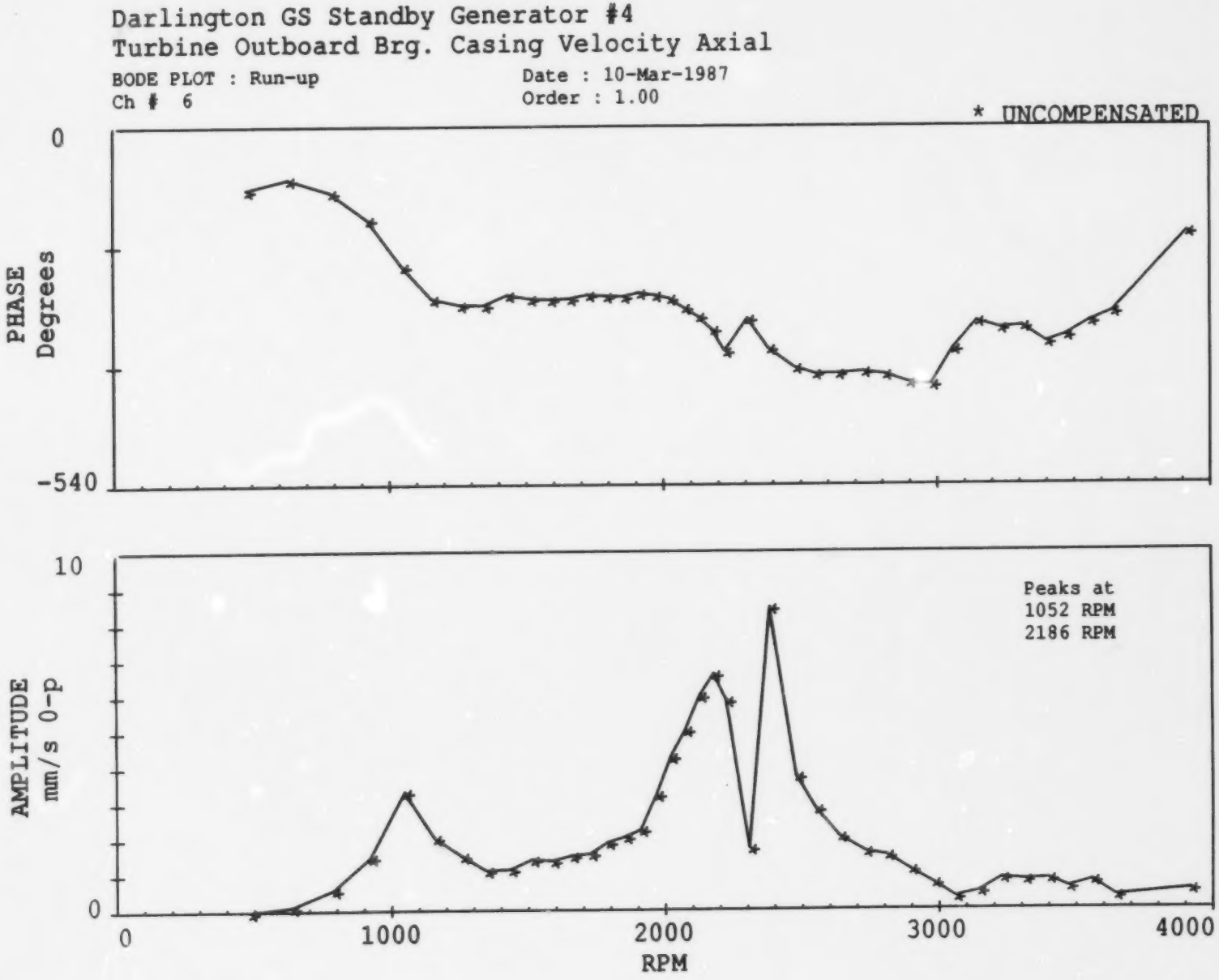
Darlington GS Standby Generator #4
Turbine Outboard Brg. Casing Velocity Axial
BODE PLOT : Run-up
Ch # 6
Date : 10-Mar-1987
Order : 1.00
* UNCOMPENSATED
0
PHASE
Degrees
-540
10
AMPLITUDE
mm/s 0-p
0
Peaks at
1052 RPM
2186 RPM
0
1000
2000
3000
4000
RPM

FIGURE 142

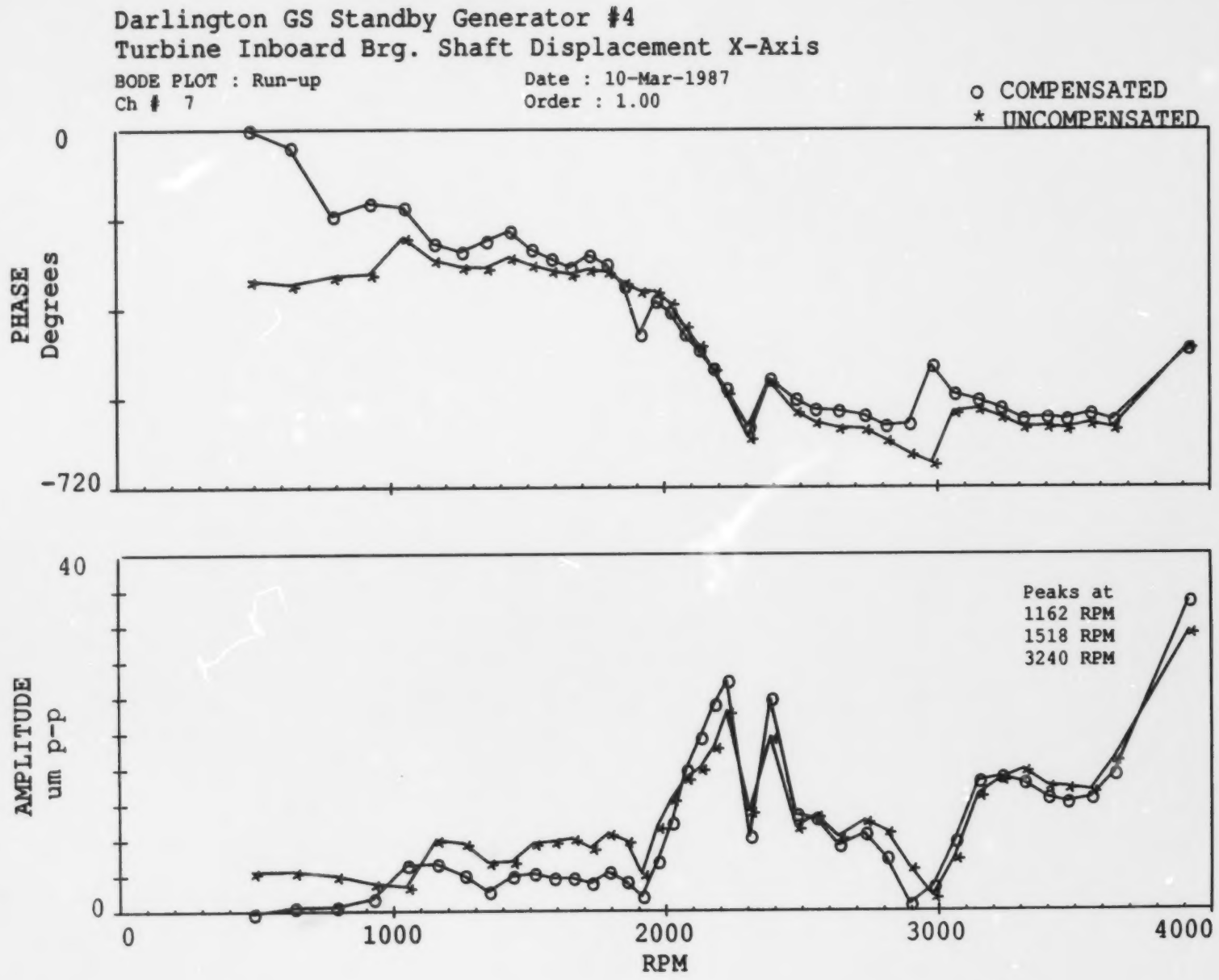
Darlington GS Standby Generator #4
Turbine Inboard Brg. Shaft Displacement X-Axis
BODE PLOT : Run-up
Ch # 7
Date : 10-Mar-1987
Order : 1.00
o COMPENSATED
* UNCOMPENSATED
0
-720
PHASE
Degrees
40
0
AMPLITUDE
um p-p
Peaks at
1162 RPM
1518 RPM
3240 RPM
0
1000
2000
3000
4000
RPM

FIGURE 143

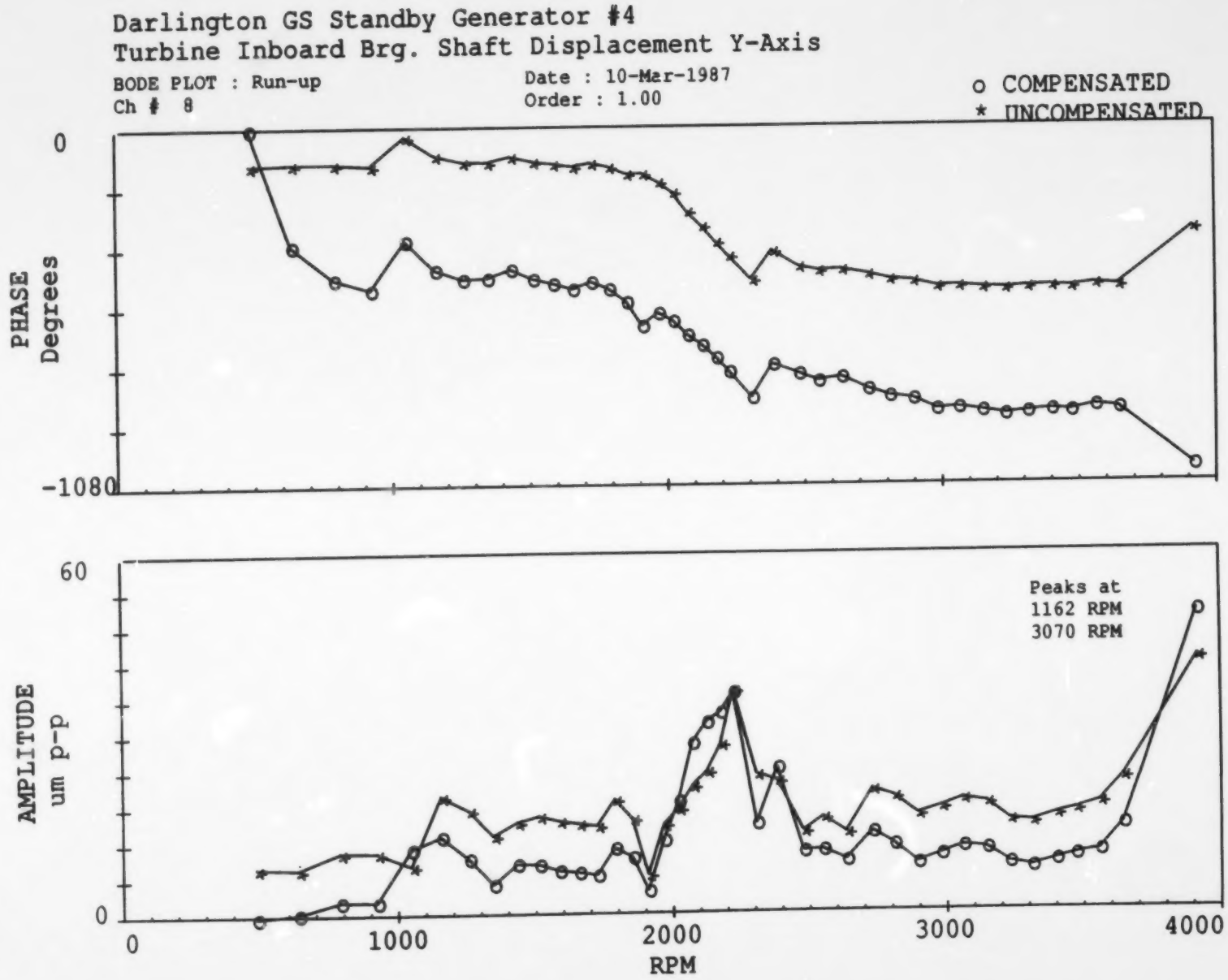
Darlington GS Standby Generator #4
Turbine Inboard Brg. Shaft Displacement Y-Axis
BODE PLOT : Run-up
Ch # 8
Date : 10-Mar-1987
Order : 1.00
o COMPENSATED
* UNCOMPENSATED
PHASE
Degrees
0
-1080
AMPLITUDE
um p-p
60
0
Peaks at
1162 RPM
3070 RPM
0
1000
2000
3000
4000
RPM

FIGURE 144

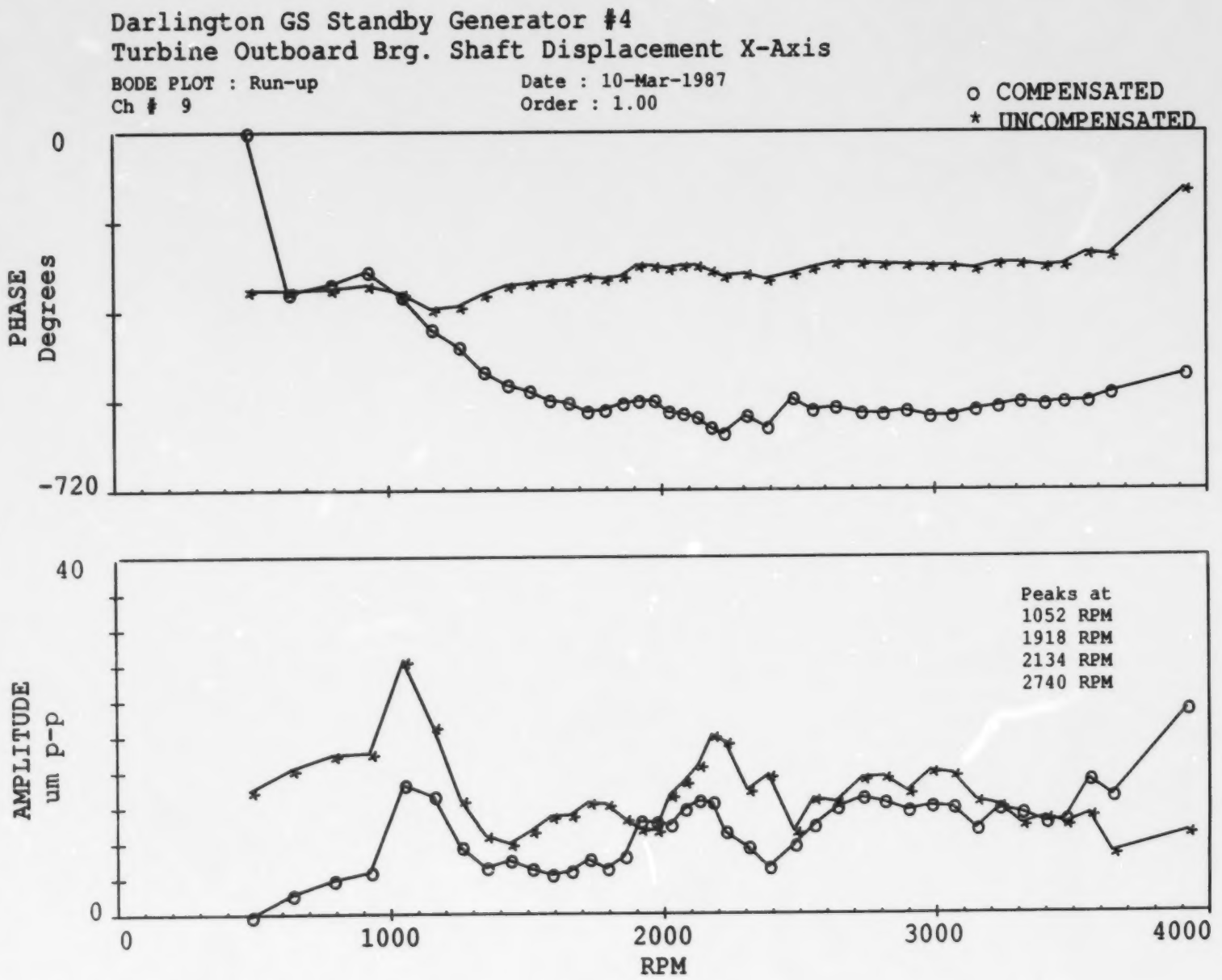
Darlington GS Standby Generator #4
Turbine Outboard Brg. Shaft Displacement X-Axis
BODE PLOT : Run-up
Ch # 9
Date : 10-Mar-1987
Order : 1.00
o COMPENSATED
* UNCOMPENSATED
0
PHASE
Degrees
-720
40
AMPLITUDE
um p-p
0
Peaks at
1052 RPM
1918 RPM
2134 RPM
2740 RPM
0
1000
2000
3000
4000
RPM

FIGURE 145

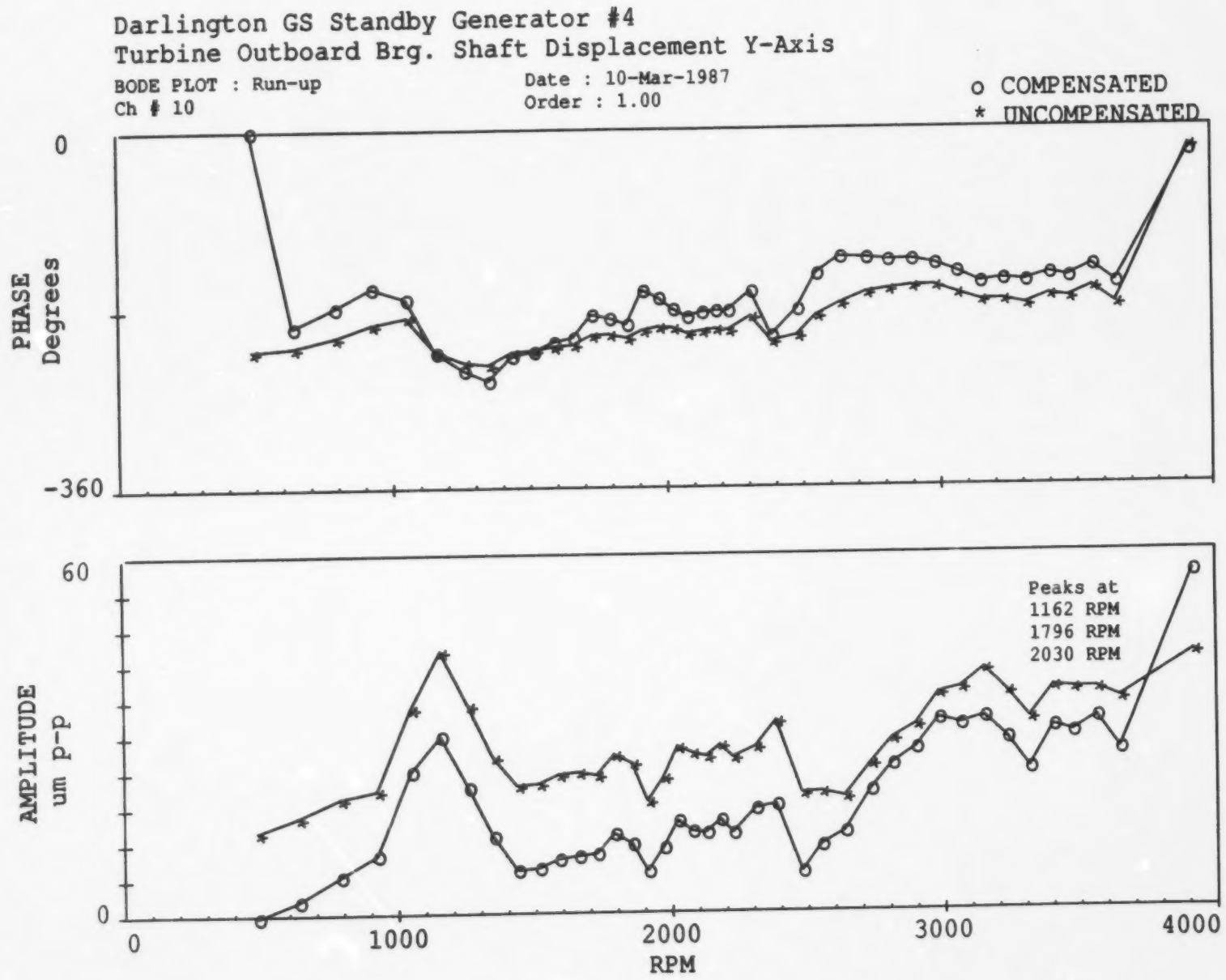
Darlington GS Standby Generator #4
Turbine Outboard Brg. Shaft Displacement Y-Axis
BODE PLOT : Run-up
Ch # 10
Date : 10-Mar-1987
Order : 1.00
o COMPENSATED
* UNCOMPENSATED
PHASE
Degrees
0
-360
AMPLITUDE
um p-p
60
0
Peaks at
1162 RPM
1796 RPM
2030 RPM
0
1000
2000
3000
4000
RPM

FIGURE 146

Darlington GS Standby Generator #4
AC Generator

RPM SPECTRAL MAP : Run-up
Date : 10-Mar-1987

Ch # 2 Outboard Brg. Casing Velocity X-Axis

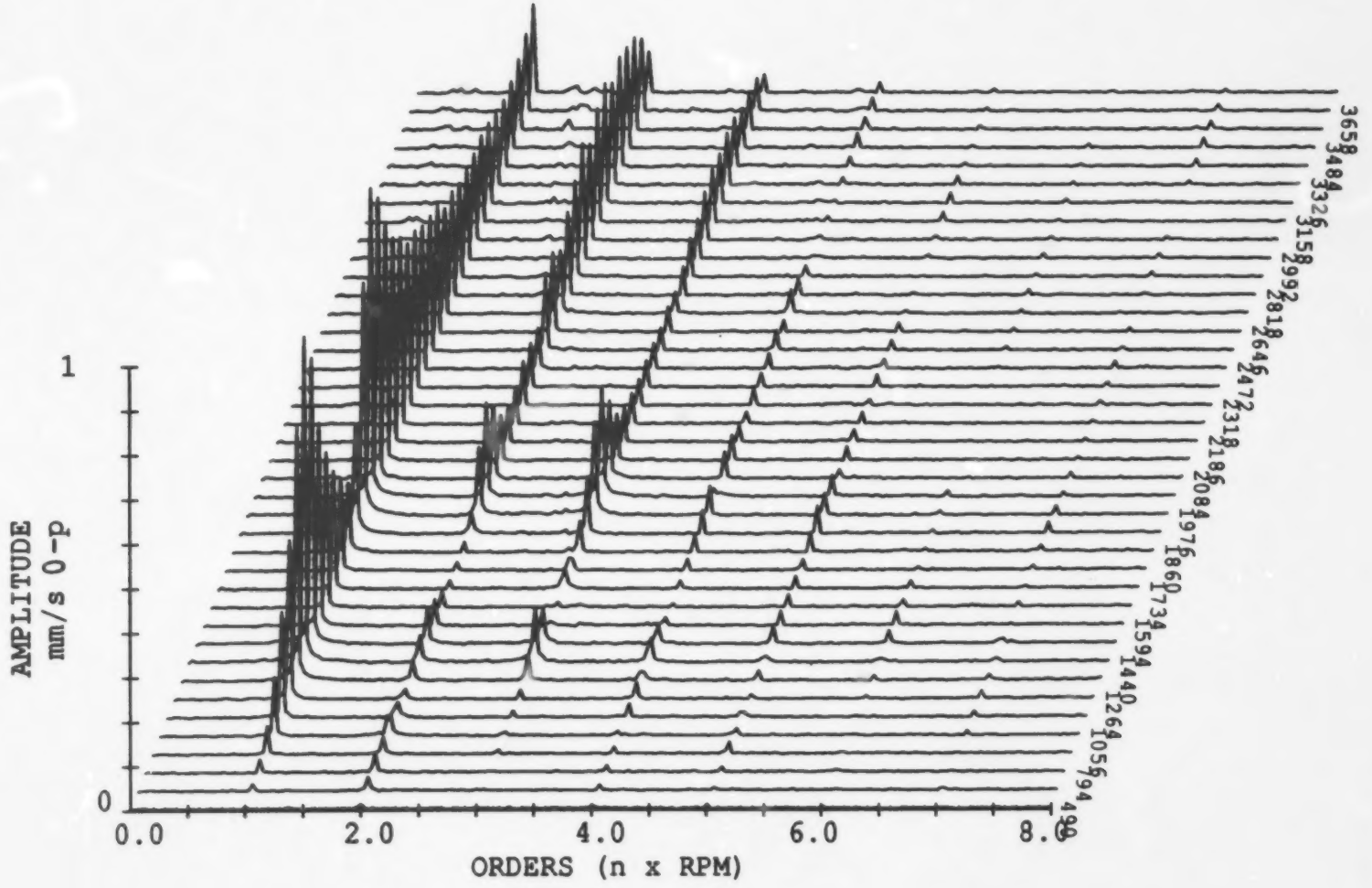

FIGURE 147

89-6

Darlington GS Standby Generator #4
AC Generator

RPM SPECTRAL MAP : Run-up
Date : 10-Mar-1987

Ch # 1 Outboard Brg. Casing Velocity Y-Axis

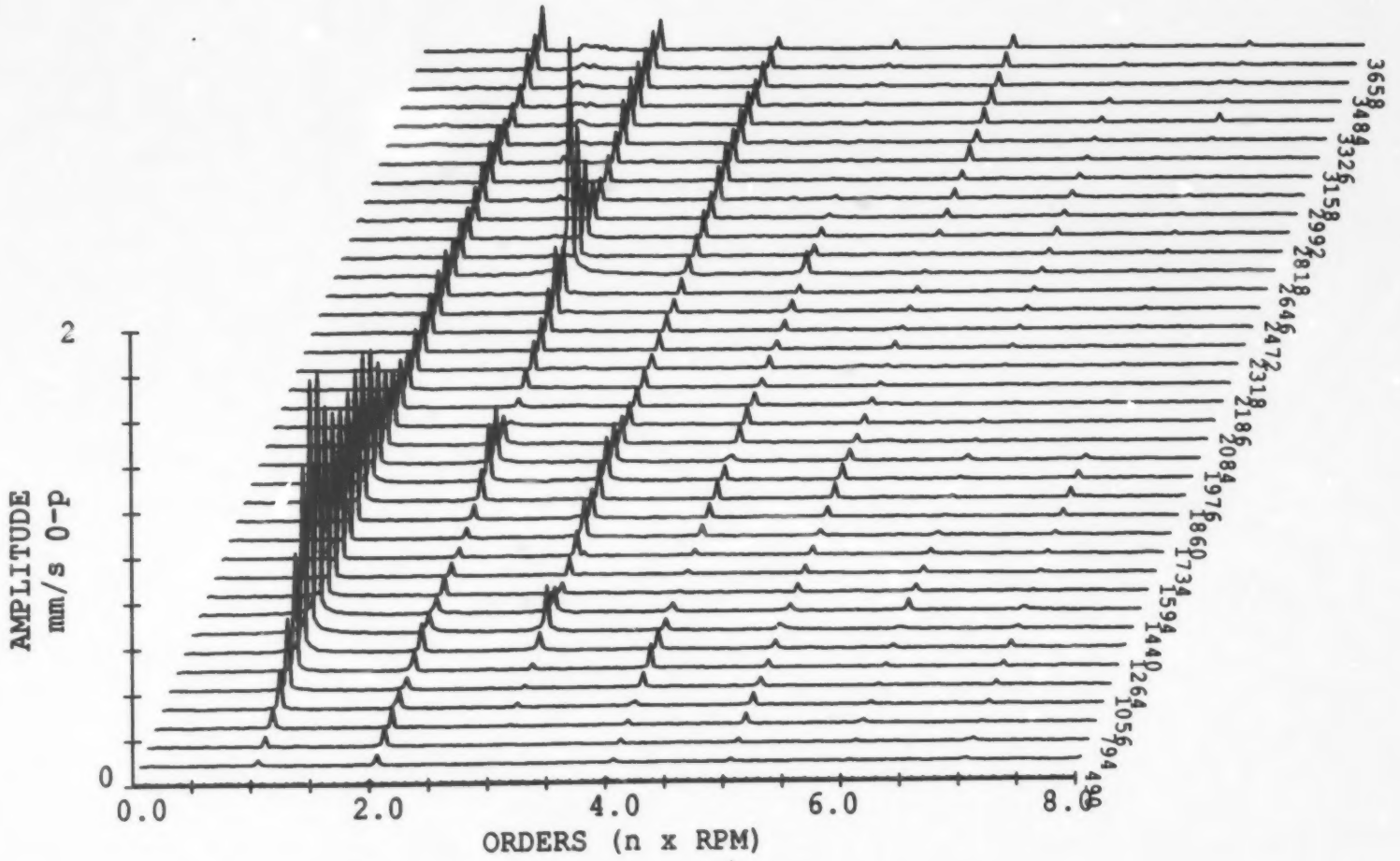

FIGURE 148

89-6

Darlington GS Standby Generator #4
AC Generator

RPM SPECTRAL MAP : Run-up
Date : 10-Mar-1987

Ch # 3 Outboard Brg. Casing Velocity Axial

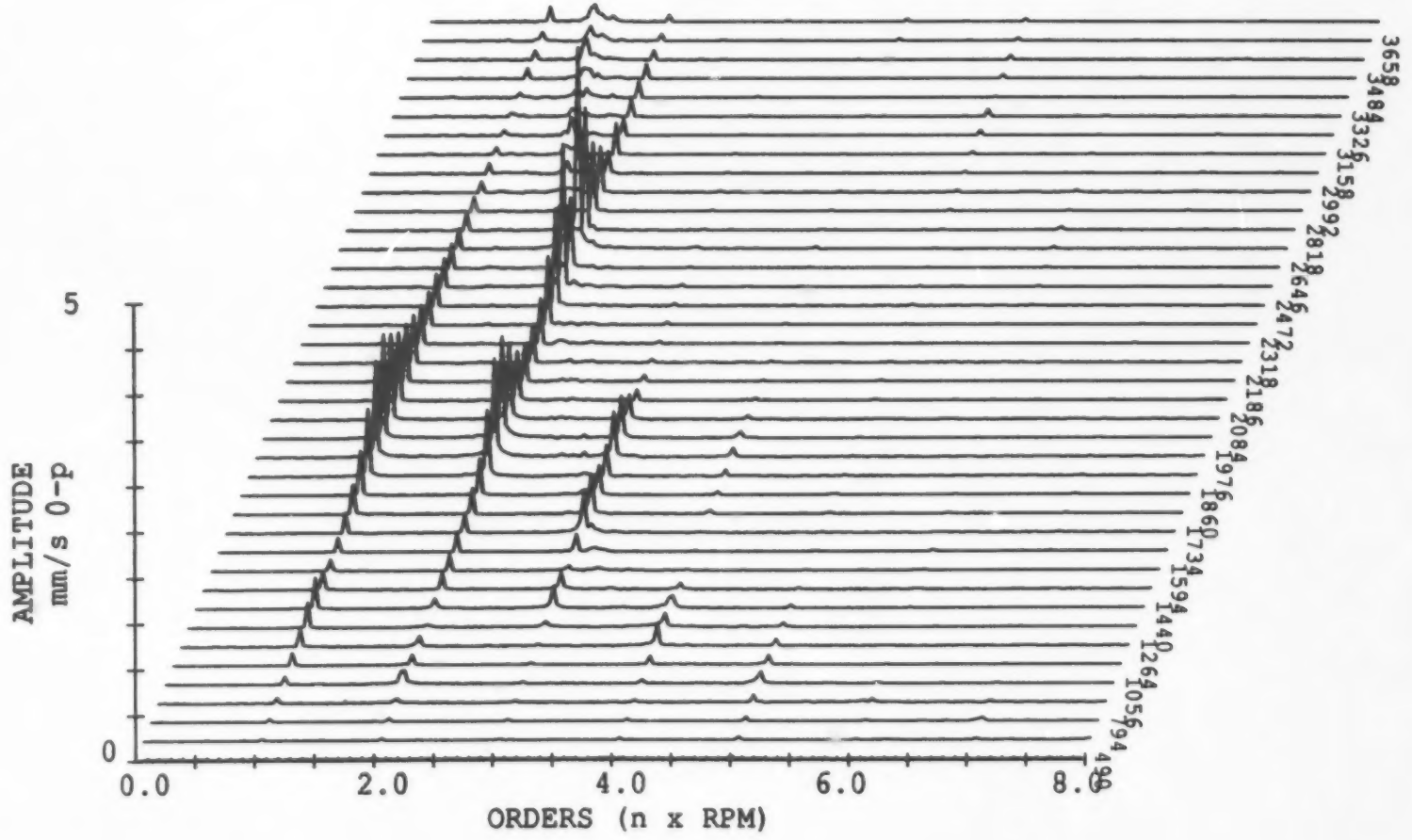

FIGURE 149

89-6

Darlington GS Standby Generator #4
AC Generator

RPM SPECTRAL MAP : Run-up
Date : 10-Mar-1987

Ch # 5 Inboard Brg. Casing Velocity X-Axis

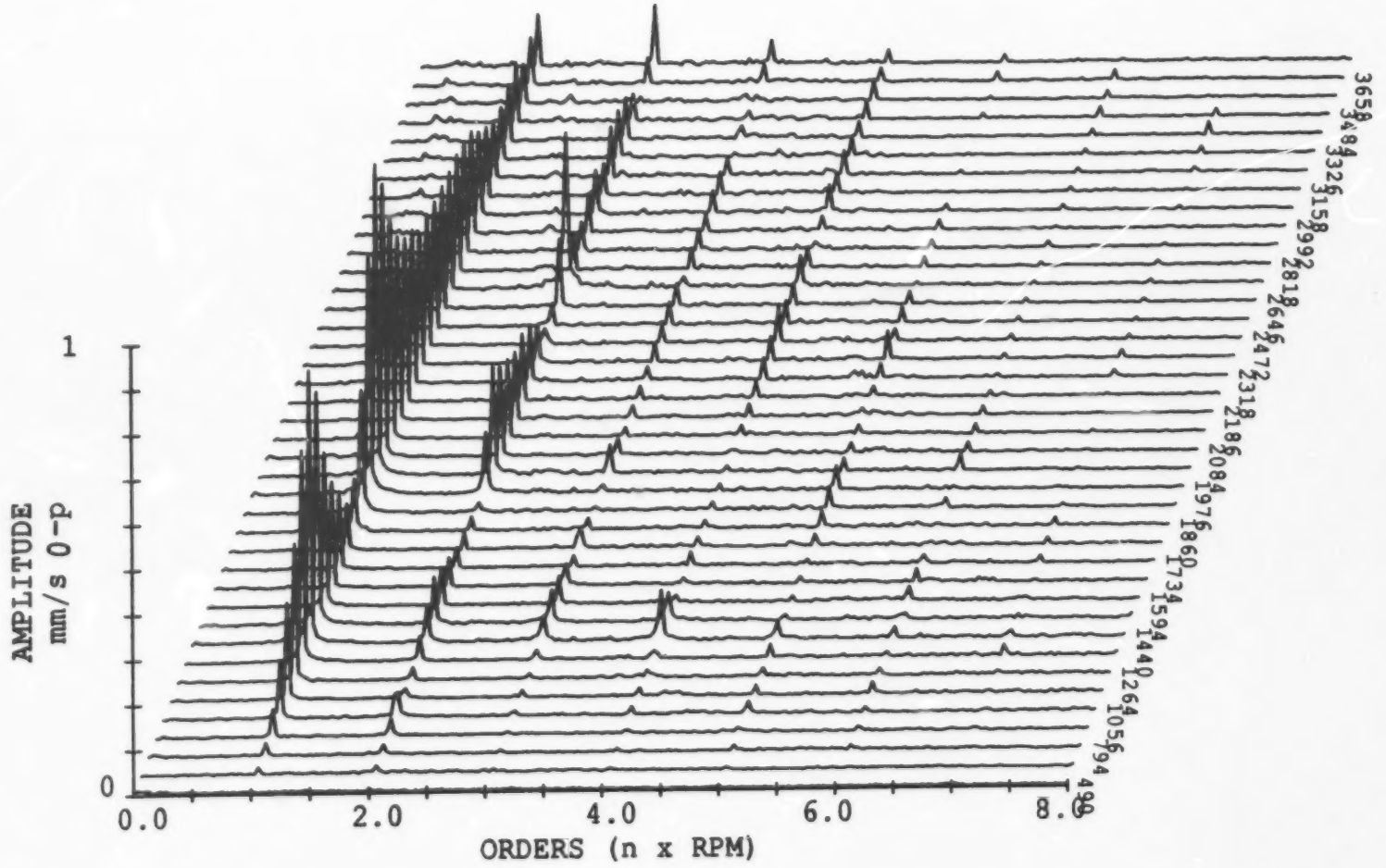

FIGURE 150

89-6

Darlington GS Standby Generator #4
AC Generator

RPM SPECTRAL MAP : Run-up
Date : 10-Mar-1987

Ch # 4 Inboard Brg. Casing Velocity Y-Axis

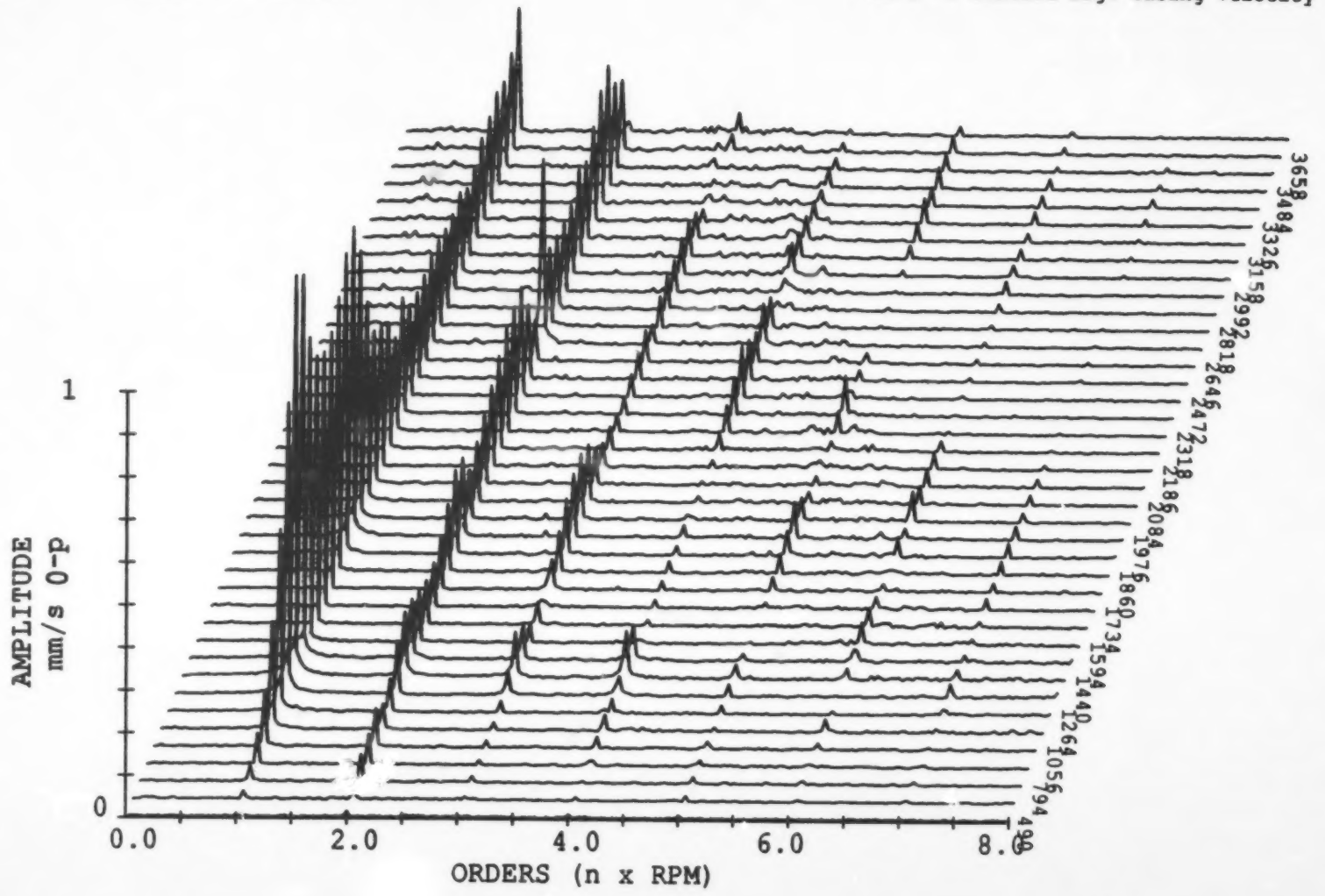

FIGURE 151

89-6

Darlington GS Standby Generator #4
AC Generator

RPM SPECTRAL MAP : Run-up
Date : 10-Mar-1987

Ch # 6 Inboard Brg. Casing Velocity Axial

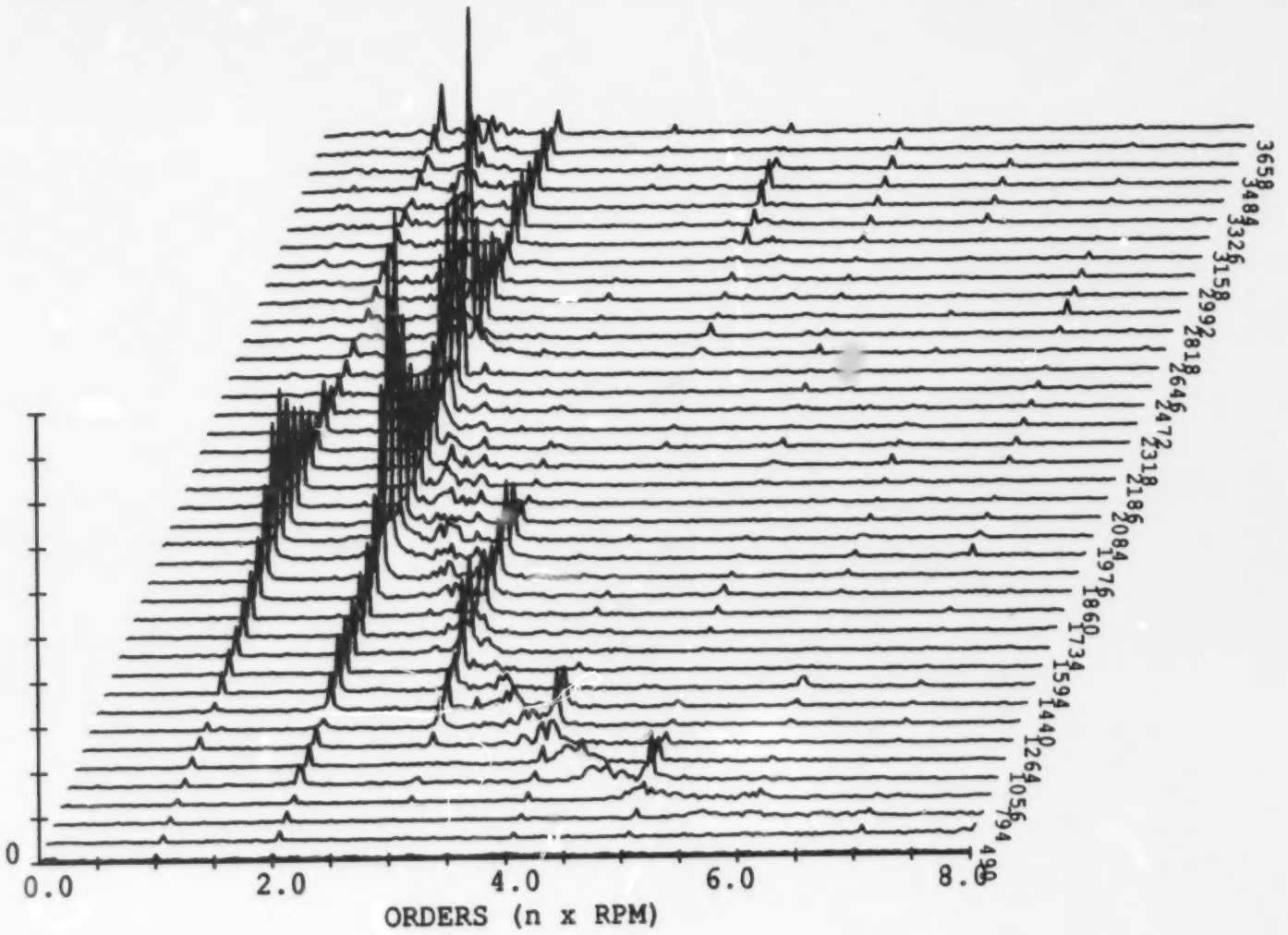

FIGURE 152

89-6

Darlington GS Standby Generator #4
AC Generator

RPM SPECTRAL MAP : Run-up
Date : 10-Mar-1987

Ch # 7 Outboard Brg. Shaft Displacement X-Axis

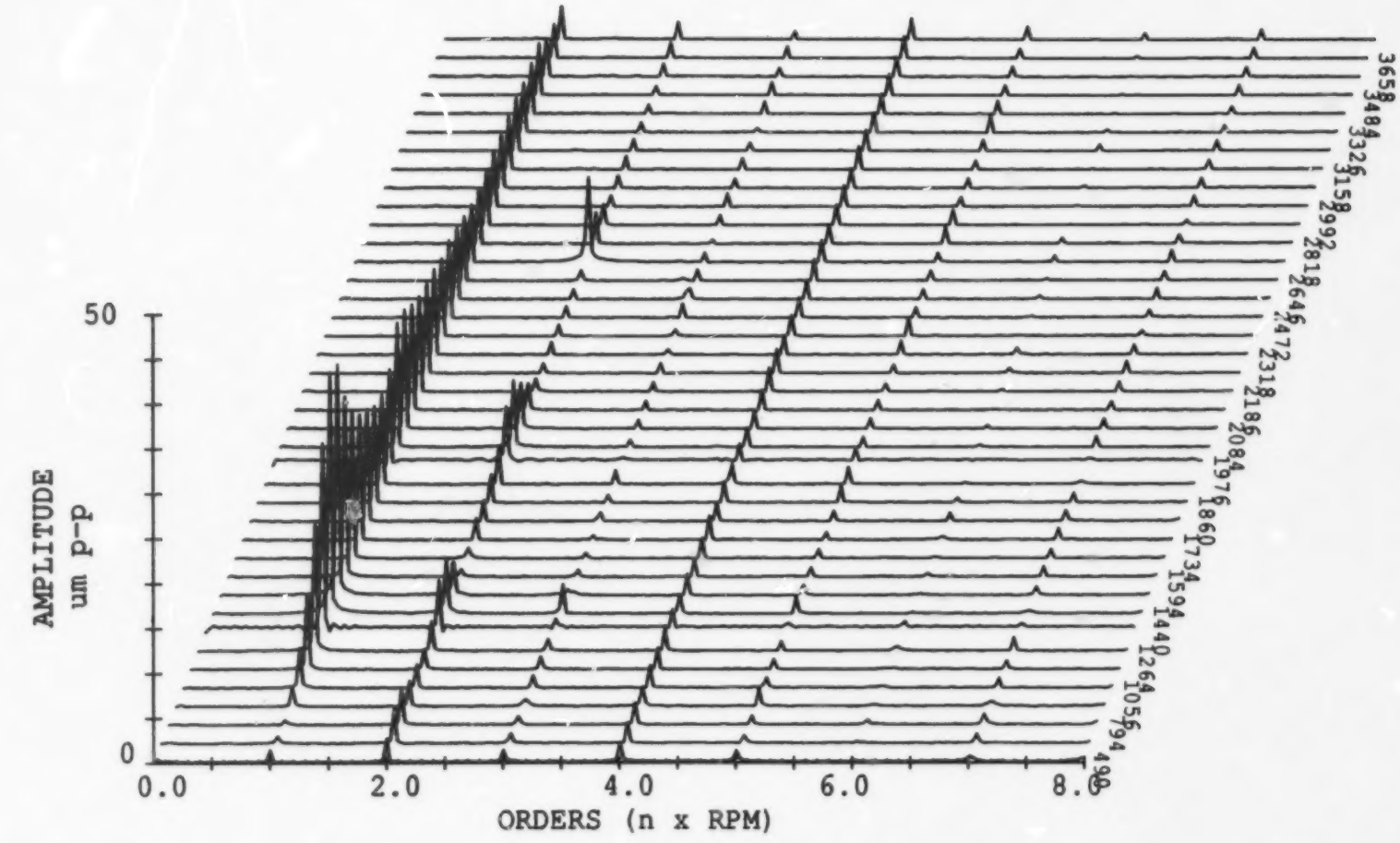

FIGURE 153

89-6

Darlington GS Standby Generator #4
AC Generator

RPM SPECTRAL MAP : Run-up
Date : 10-Mar-1987

Ch # 8 Outboard Brg. Shaft Displacement Y-Axis

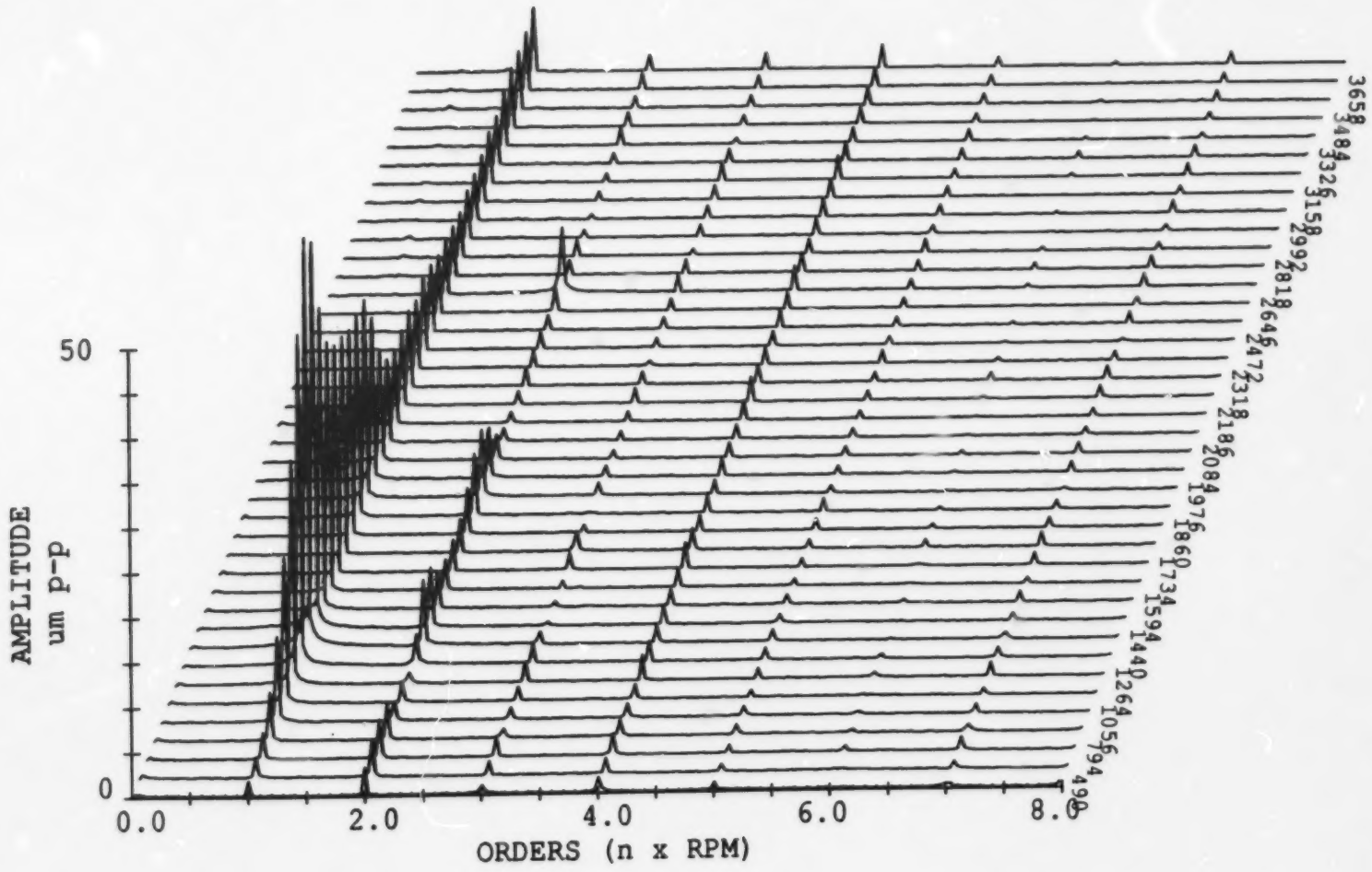

FIGURE 154

89-6

Darlington GS Standby Generator #4
AC Generator

RPM SPECTRAL MAP : Run-up
Date : 10-Mar-1987

Ch # 9 Inboard Brg. Shaft Displacement X-Axis

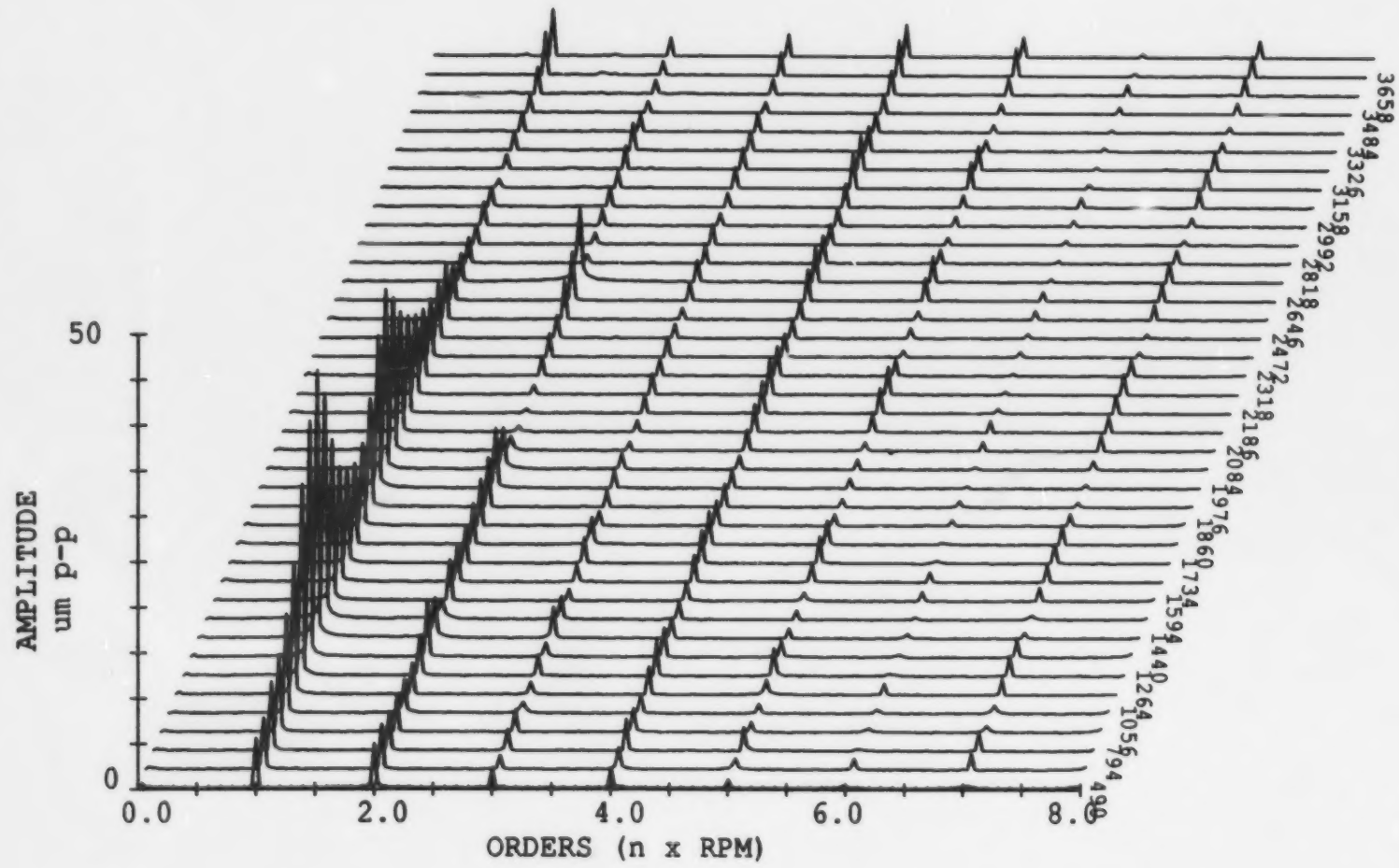

FIGURE 155

89-6

Darlington GS Standby Generator #4
AC Generator

RPM SPECTRAL MAP : Run-up
Date : 10-Mar-1987

Ch # 10 Inboard Brg. Shaft Displacement Y-Axis

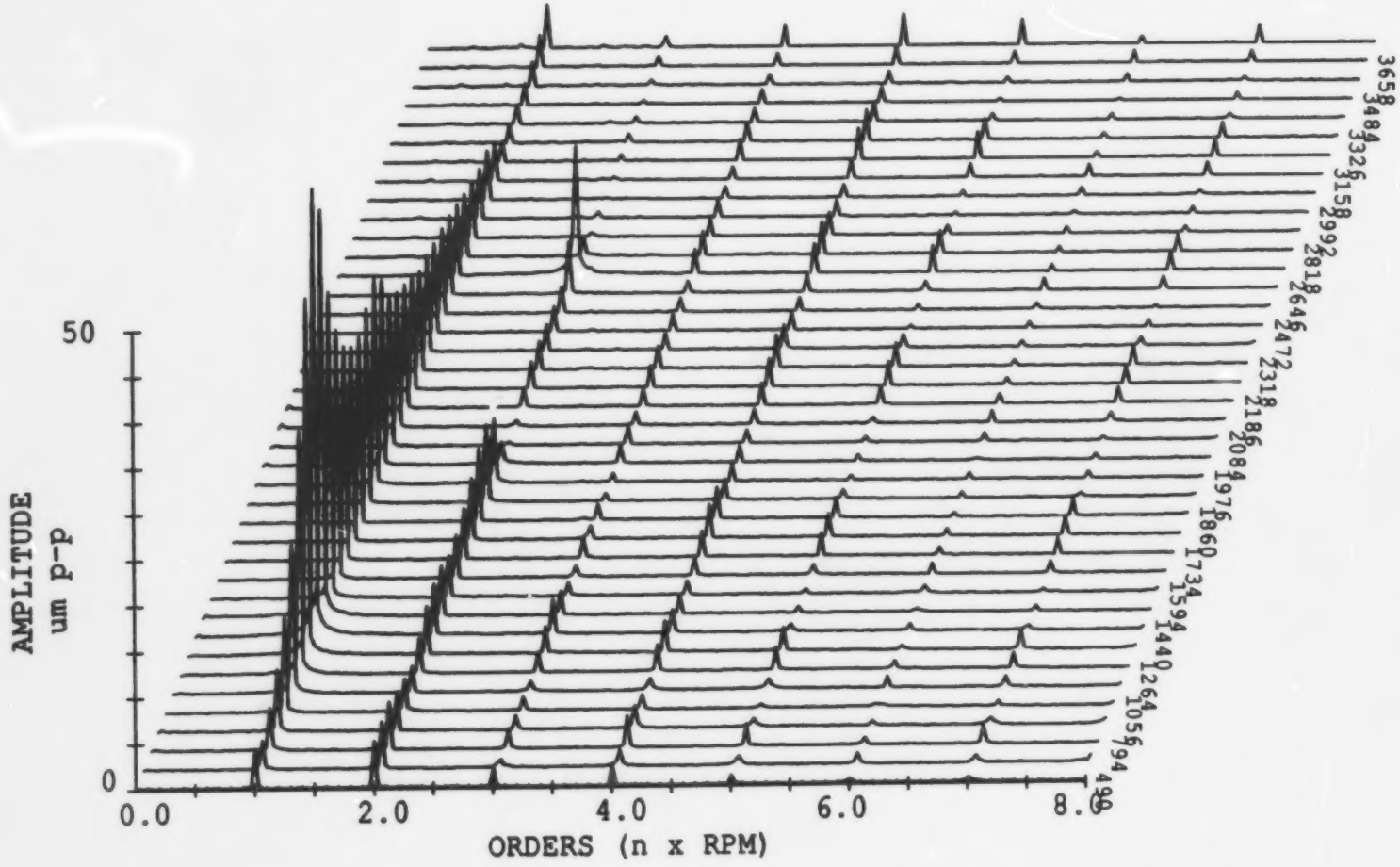

FIGURE 156

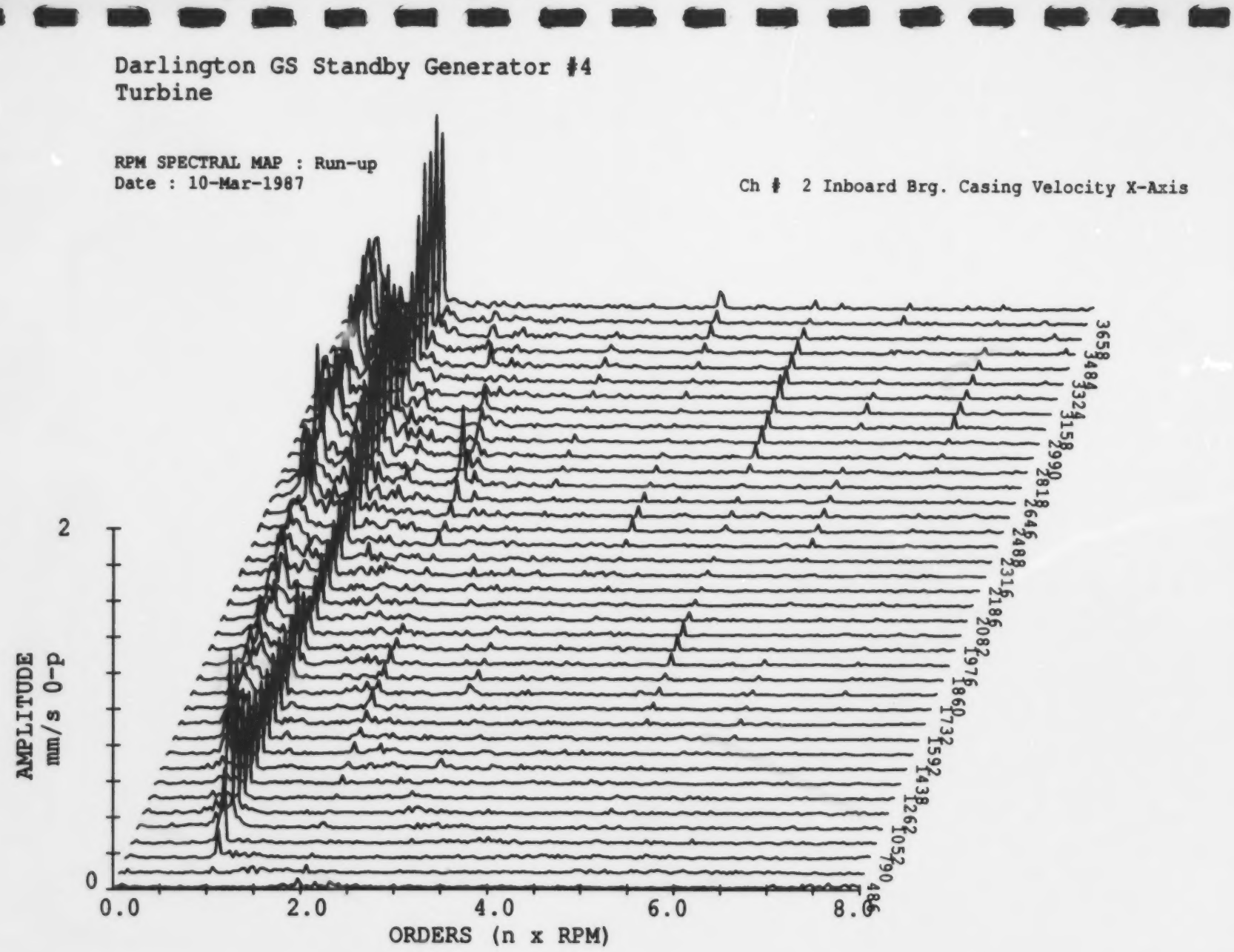

FIGURE 157

89-6

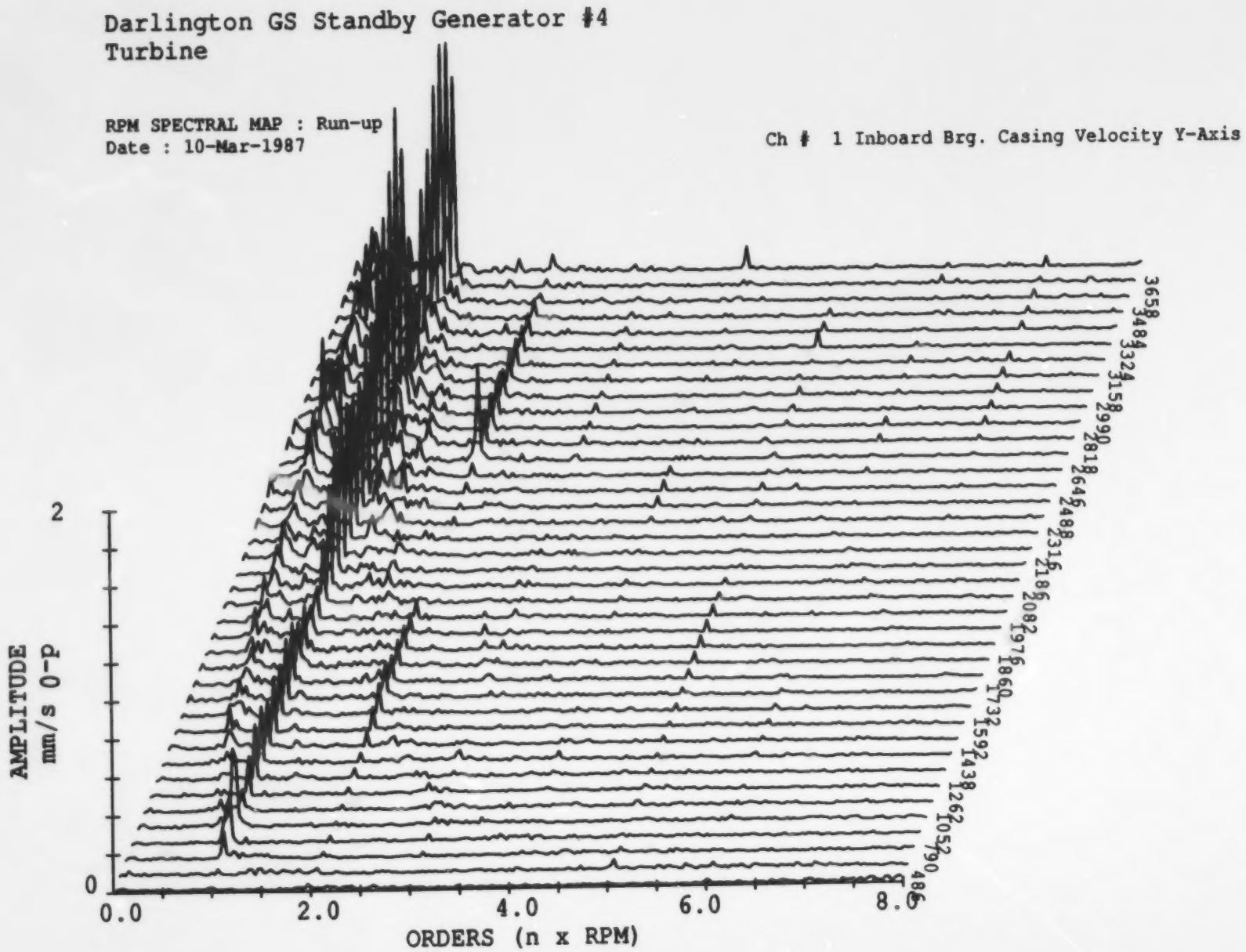
Darlington GS Standby Generator #4
Turbine
RPM SPECTRAL MAP : Run-up
Date : 10-Mar-1987
Ch # 1 Inboard Brg. Casing Velocity Y-Axis
AMPLITUDE
mm/s 0-p
2
0
0.0
2.0
4.0
6.0
8.0
ORDERS (n x RPM)
3658
3484
3324
3158
2990
2818
2646
2488
2316
2186
2082
1976
1860
1732
1592
1438
1262
1052
790
486

FIGURE 158

Darlington GS Standby Generator #4
Turbine

RPM SPECTRAL MAP : Run-up
Date : 10-Mar-1987

Ch # 3 Inboard Brg. Casing Velocity Axial

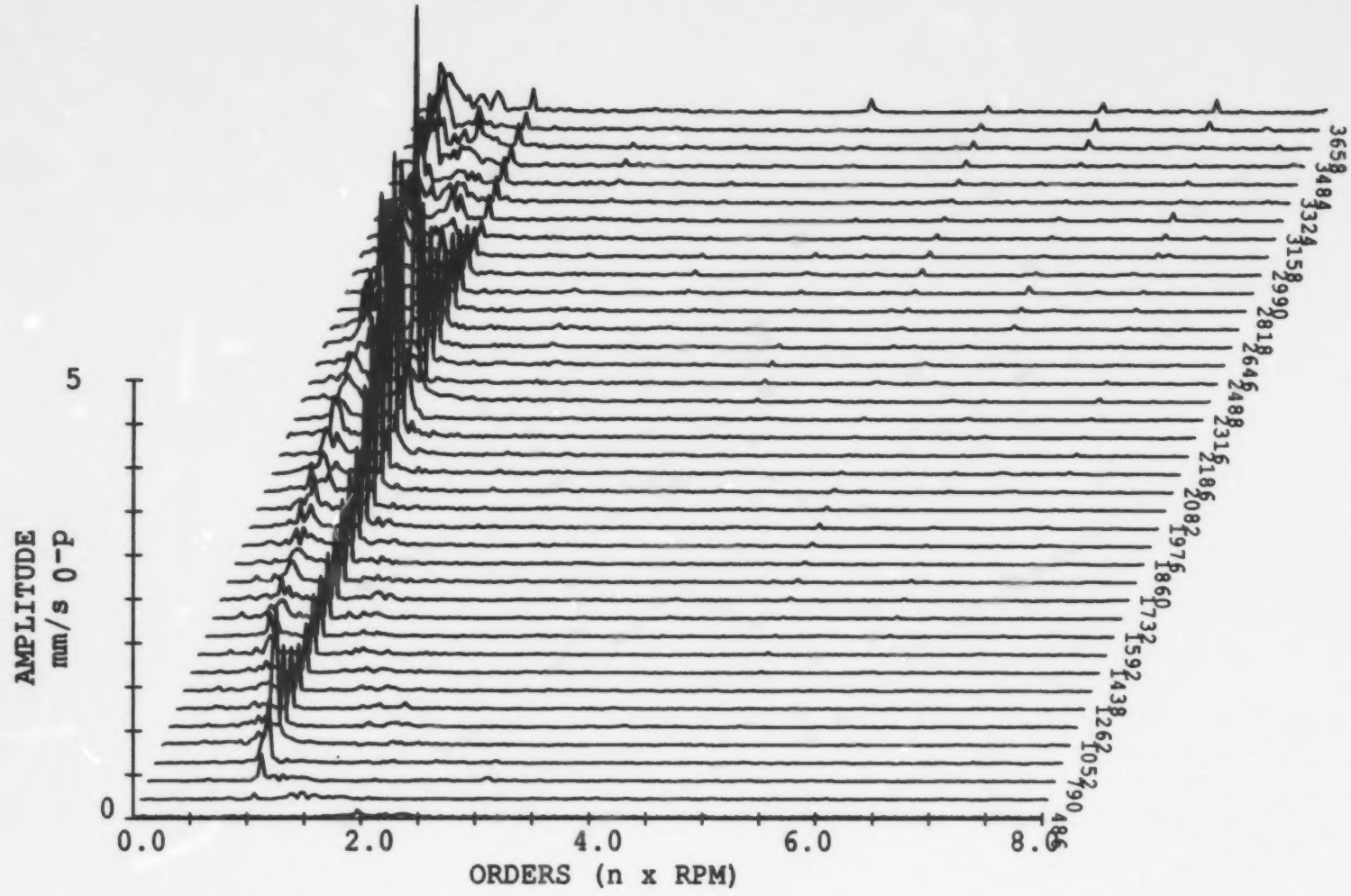

FIGURE 159

89-6

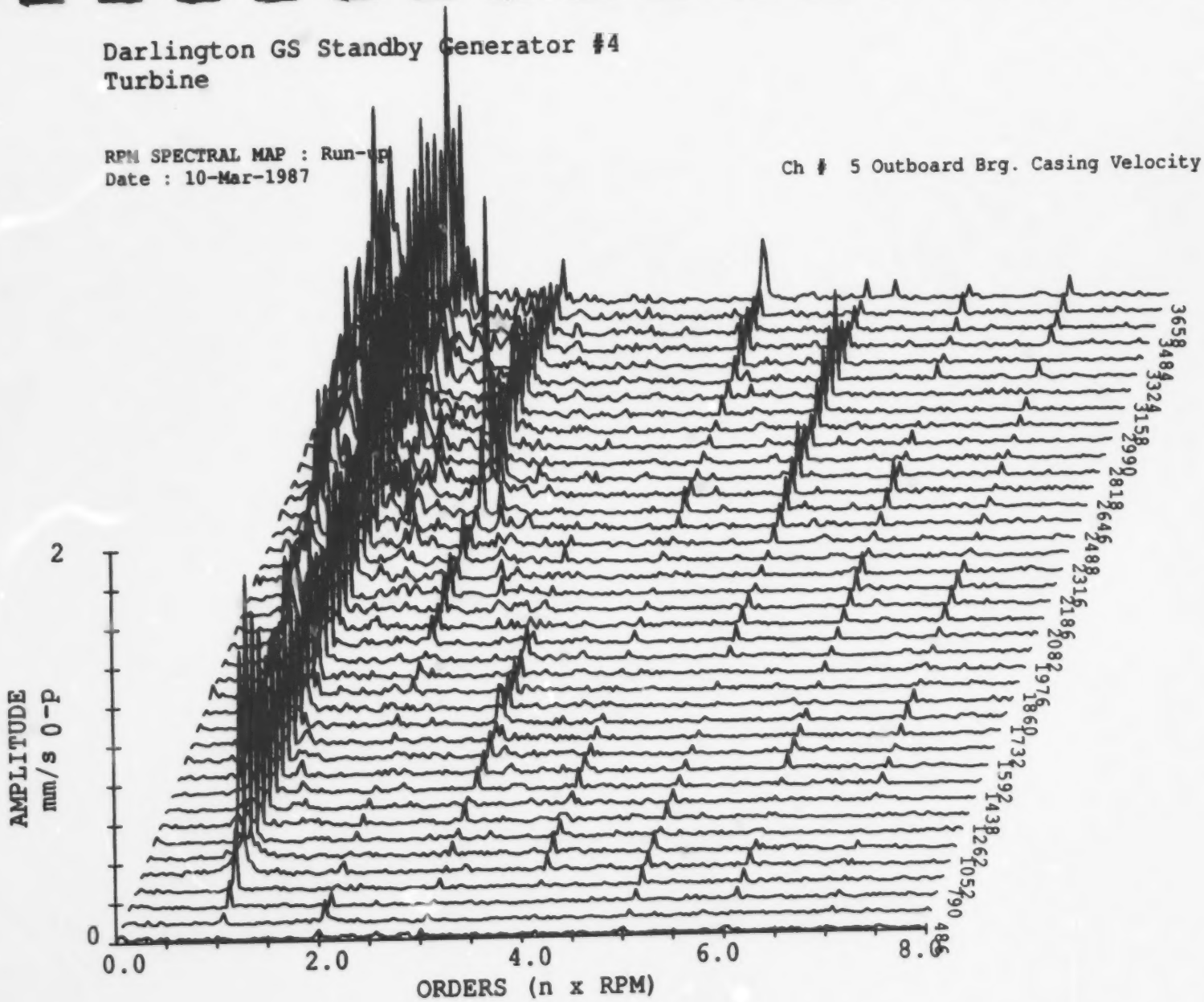
Darlington GS Standby Generator #4
Turbine
RPM SPECTRAL MAP : Run-up
Date : 10-Mar-1987
Ch # 5 Outboard Brg. Casing Velocity Horiz.
AMPLITUDE
mm/s 0-p
2
0
0.0
2.0
4.0
6.0
8.
ORDERS (n x RPM)
3658
3484
3324
3158
2990
2818
2646
2488
2316
2186
2082
1976
1860
1732
1592
1438
1262
1052
790
486

FIGURE 160

Darlington GS Standby Generator #4
Turbine

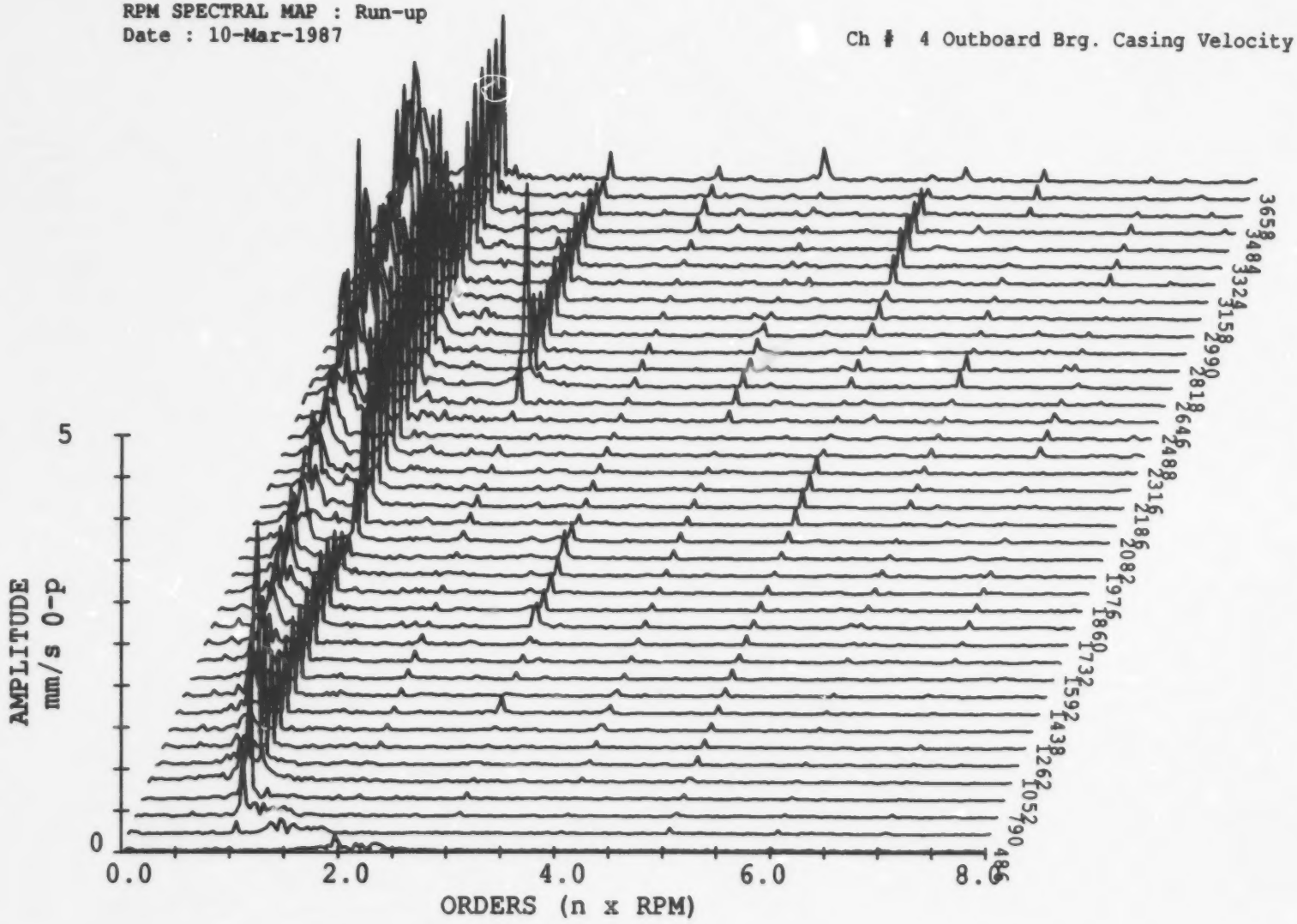

FIGURE 161

Darlington GS Standby Generator #4
Turbine

RPM SPECTRAL MAP : Run-up
Date : 10-Mar-1987

Ch # 6 Outboard Brg. Casing Velocity Axial

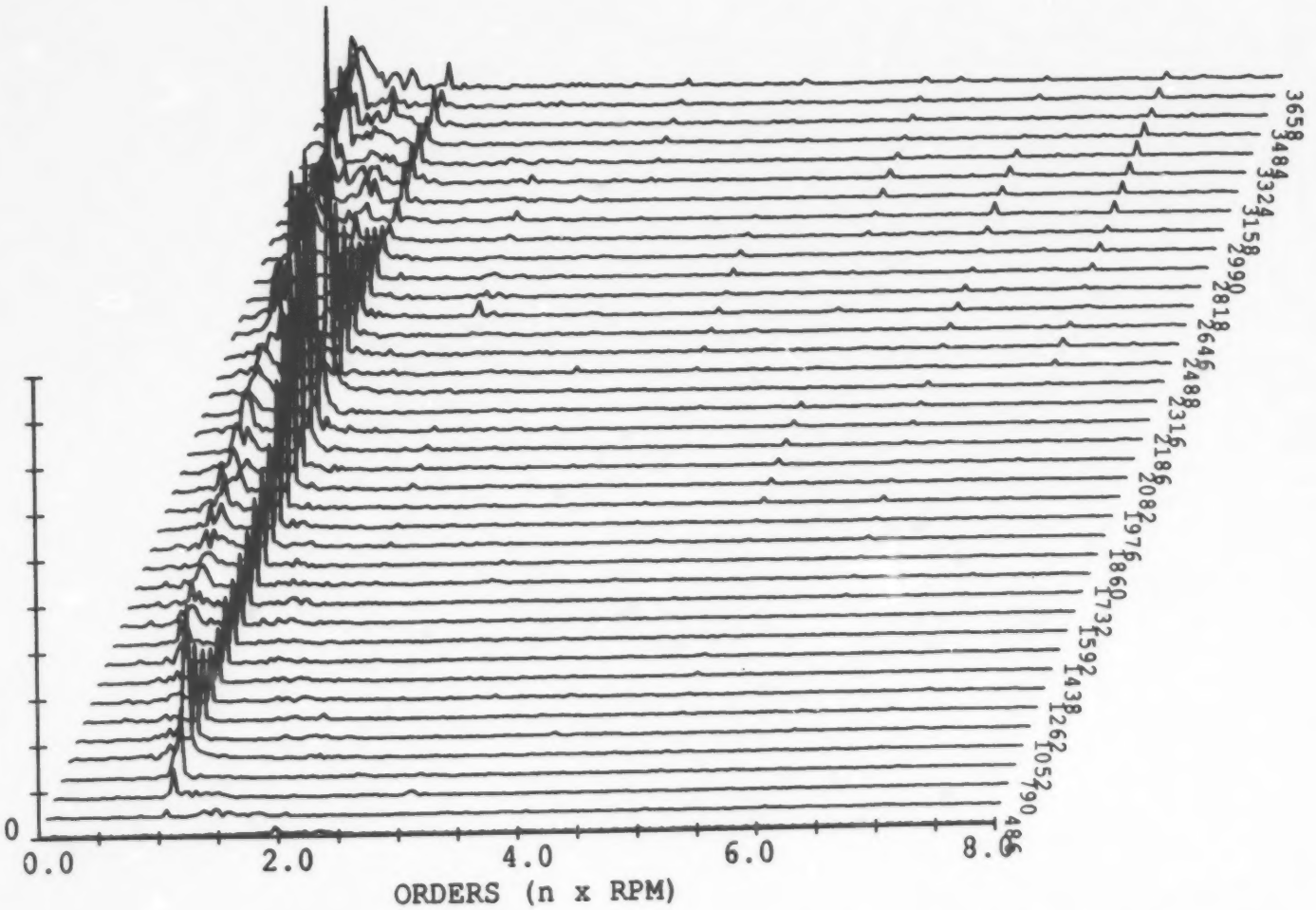

FIGURE 162

89-6

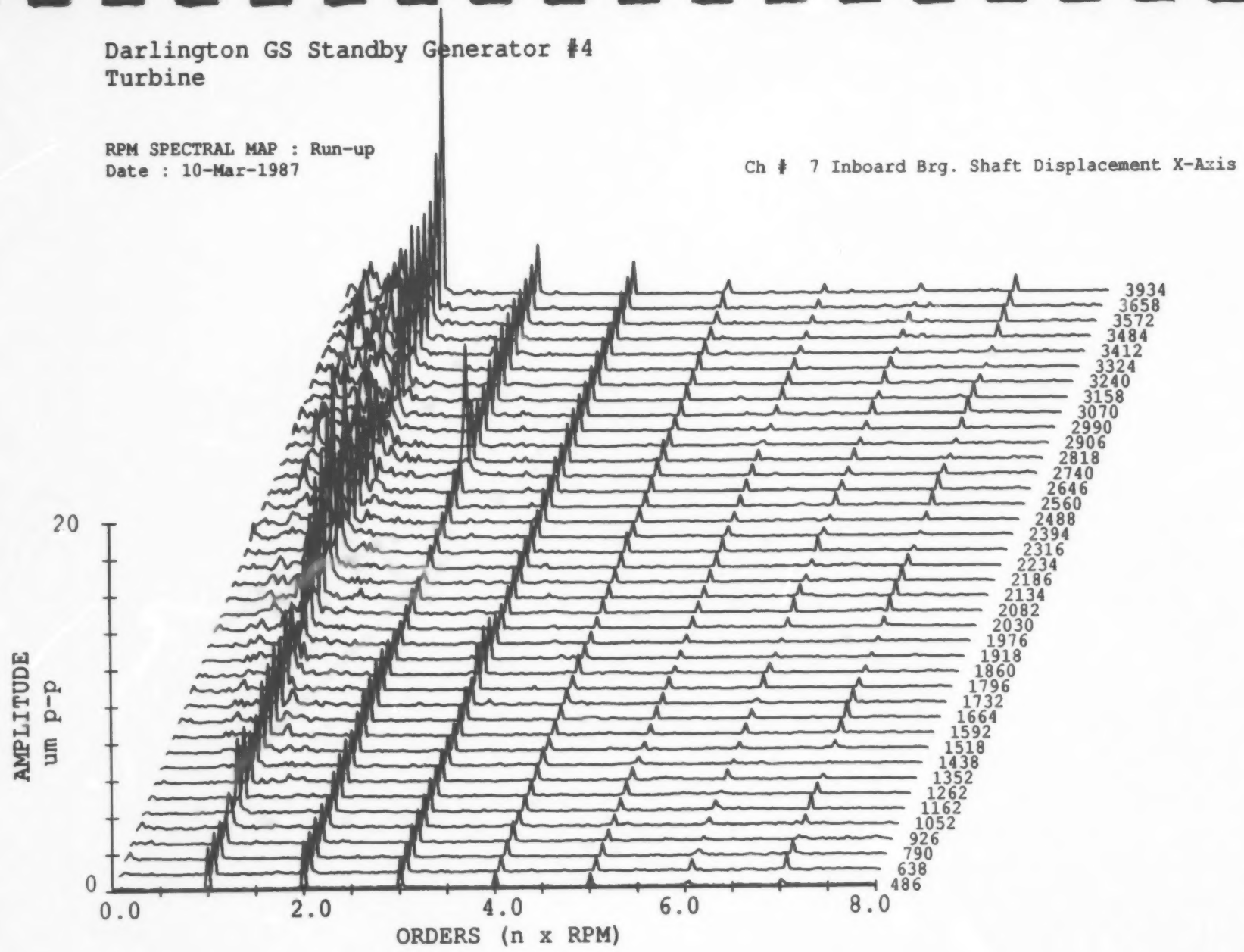

FIGURE 163

89-6

Darlington GS Standby Generator #4
Turbine

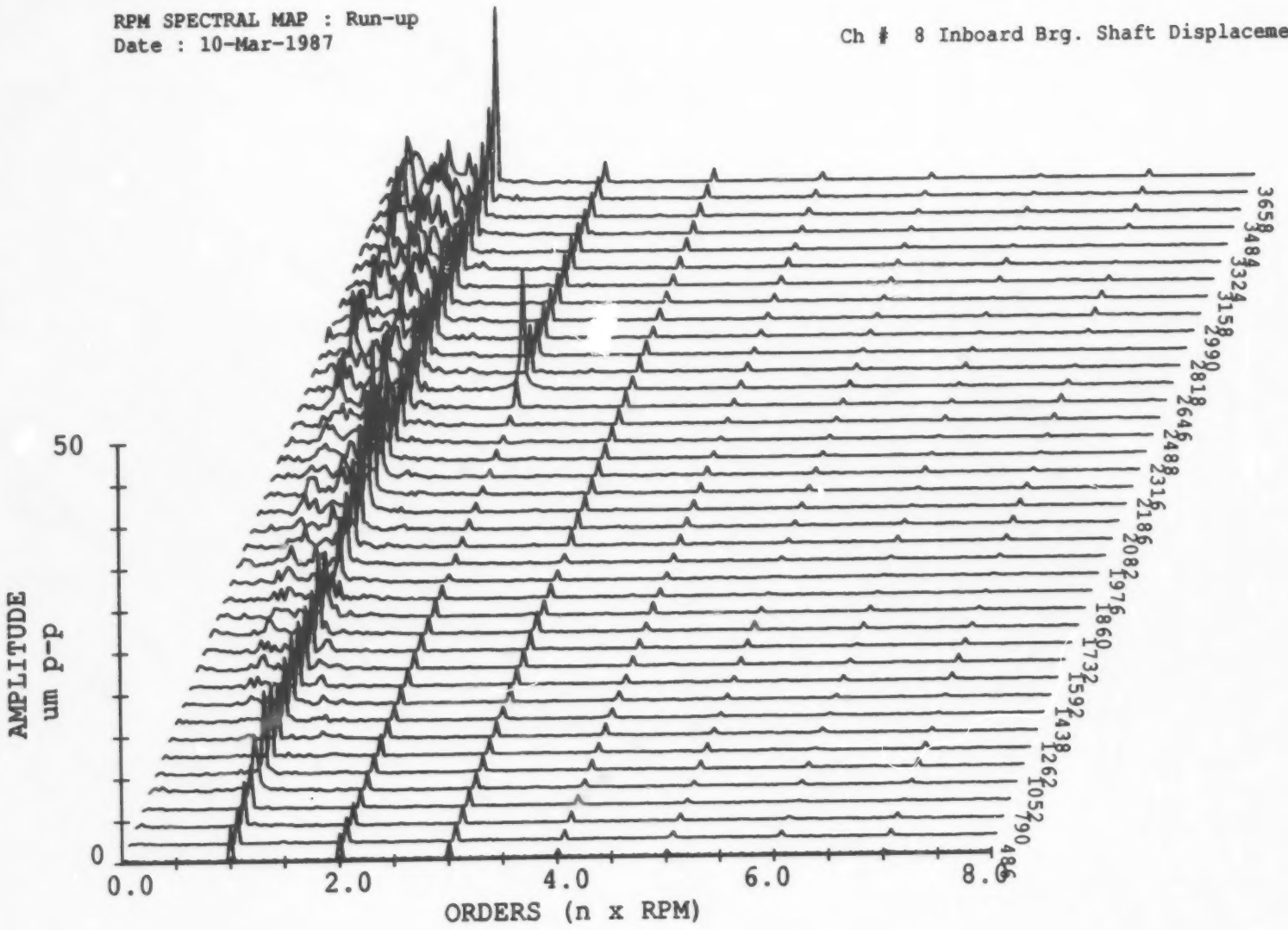

FIGURE 164

89-6

Darlington GS Standby Generator #4
Turbine

RPM SPECTRAL MAP : Run-up
Date : 10-Mar-1987

Ch # 9 Outboard Brg. Shaft Displacement X-Axis

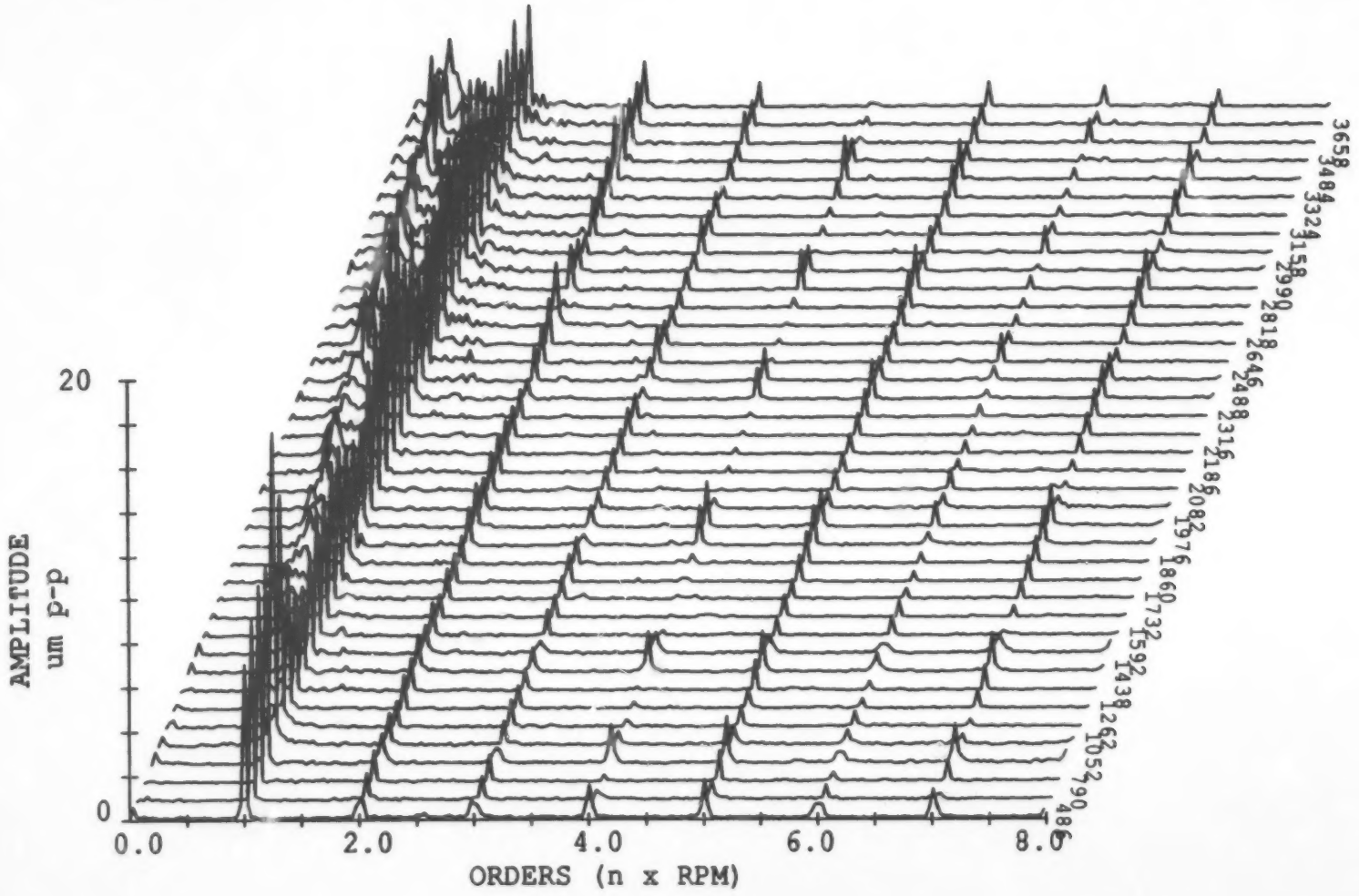

FIGURE 165

89-68

Darlington GS Standby Generator #4
Turbine

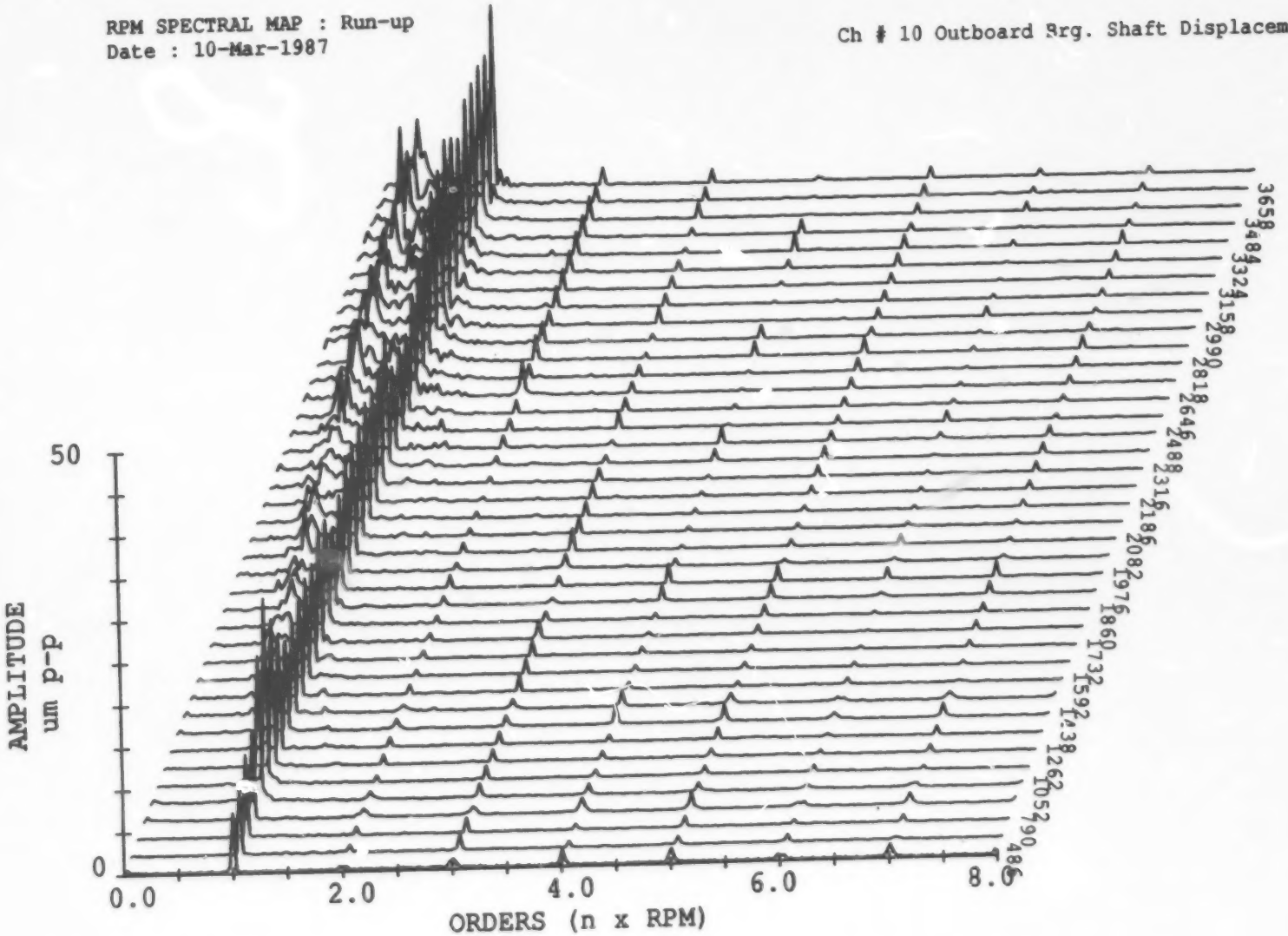

FIGURE 166

89-6

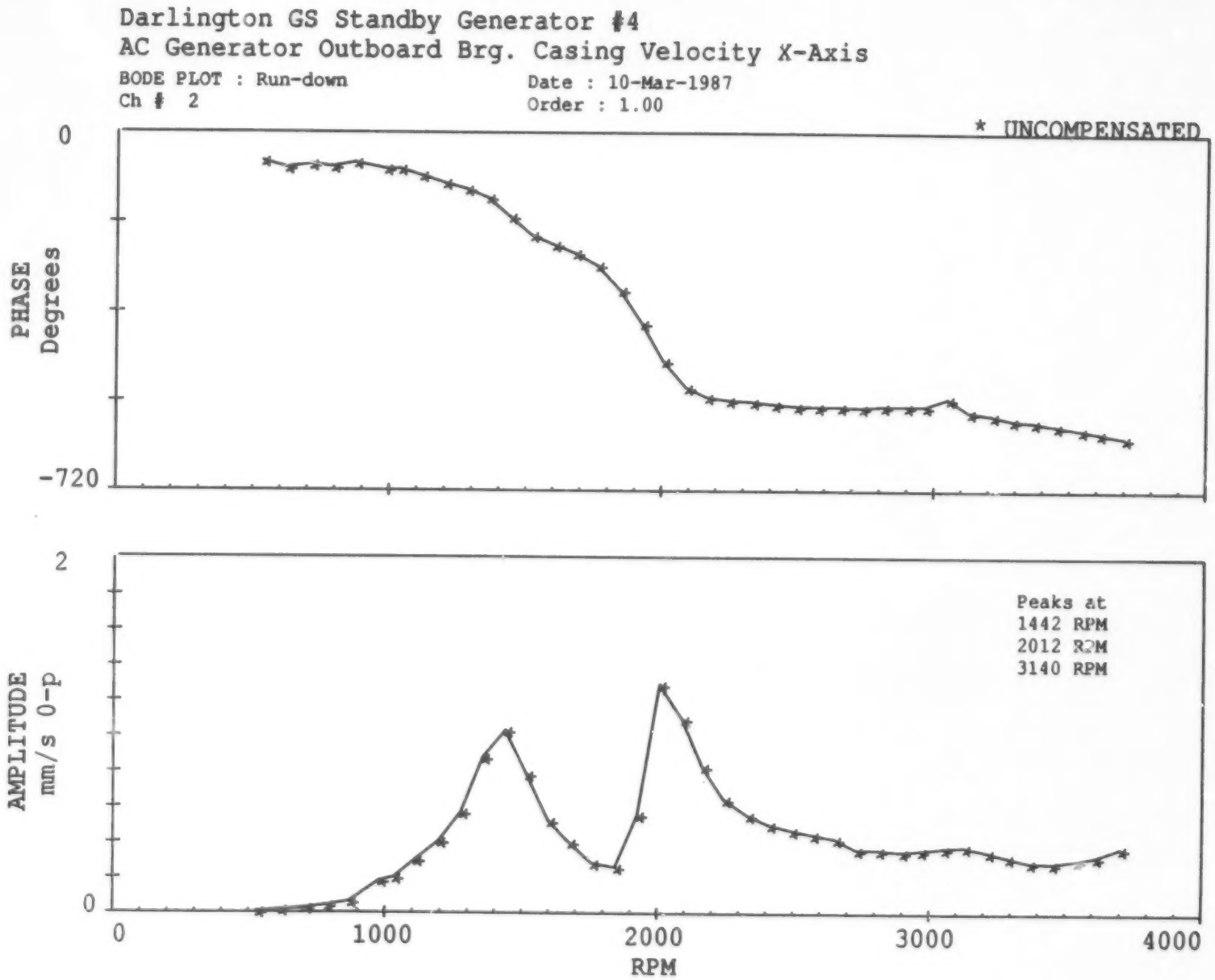
Darlington GS Standby Generator #4
AC Generator Outboard Brg. Casing Velocity X-Axis
BODE PLOT : Run-down
Ch # 2
Date : 10-Mar-1987
Order : 1.00
* UNCOMPENSATED
0
PHASE
Degrees
-720
2
AMPLITUDE
mm/s 0-p
0
Peaks at
1442 RPM
2012 RPM
3140 RPM
0
1000
2000
3000
4000
RPM

FIGURE 167

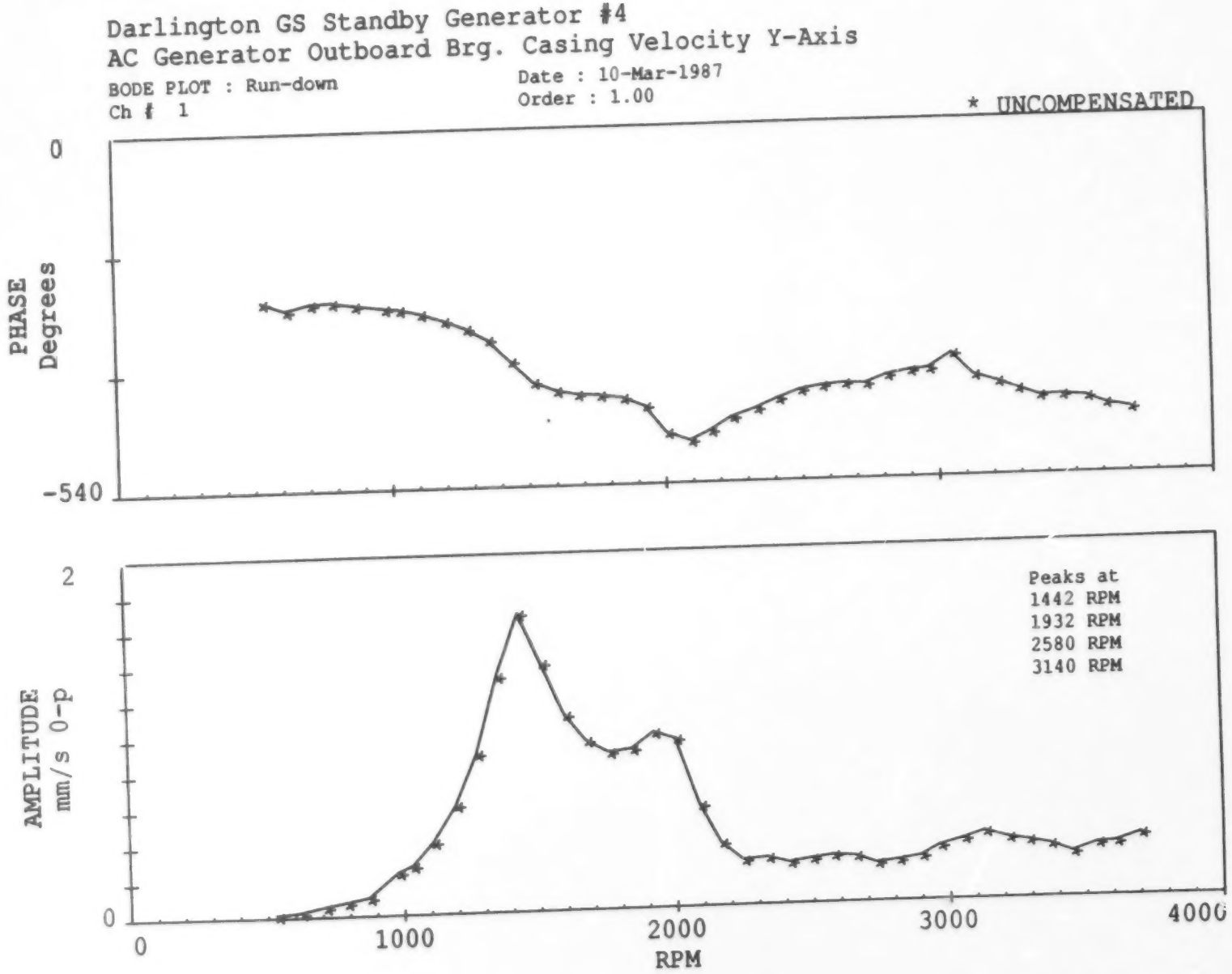
Darlington GS Standby Generator #4
AC Generator Outboard Brg. Casing Velocity Y-Axis
BODE PLOT : Run-down
Ch # 1
Date : 10-Mar-1987
Order : 1.00
* UNCOMPENSATED
0
PHASE
Degrees
-540
2
AMPLITUDE
mm/s 0-p
0
Peaks at
1442 RPM
1932 RPM
2580 RPM
3140 RPM
0
1000
2000
3000
4000
RPM

FIGURE 168

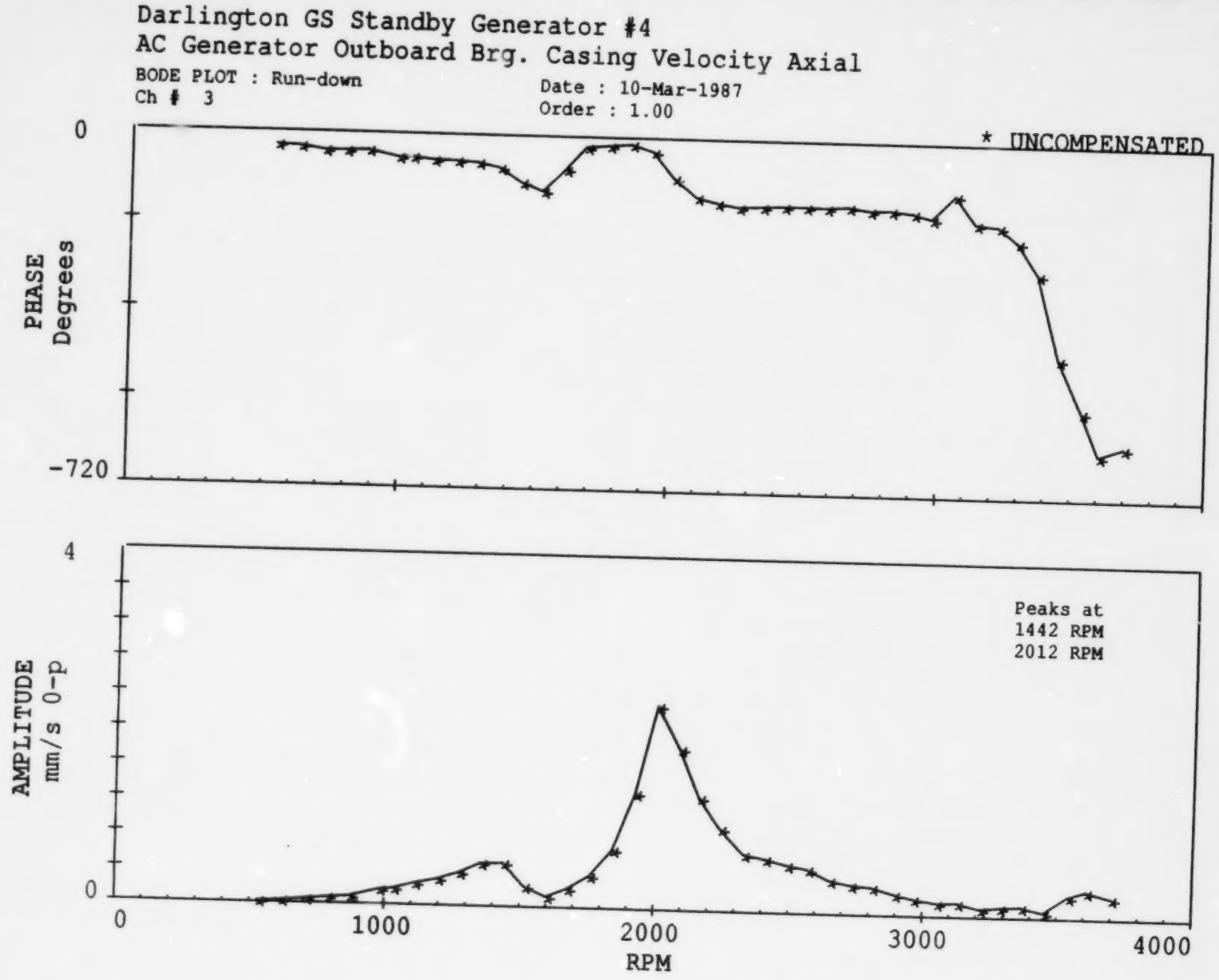
Darlington GS Standby Generator #4
AC Generator Outboard Brg. Casing Velocity Axial
BODE PLOT : Run-down
Ch # 3
Date : 10-Mar-1987
Order : 1.00
* UNCOMPENSATED
0
-720
PHASE
Degrees
4
0
AMPLITUDE
mm/s 0-p
Peaks at
1442 RPM
2012 RPM
0
1000
2000
3000
4000
RPM

FIGURE 169

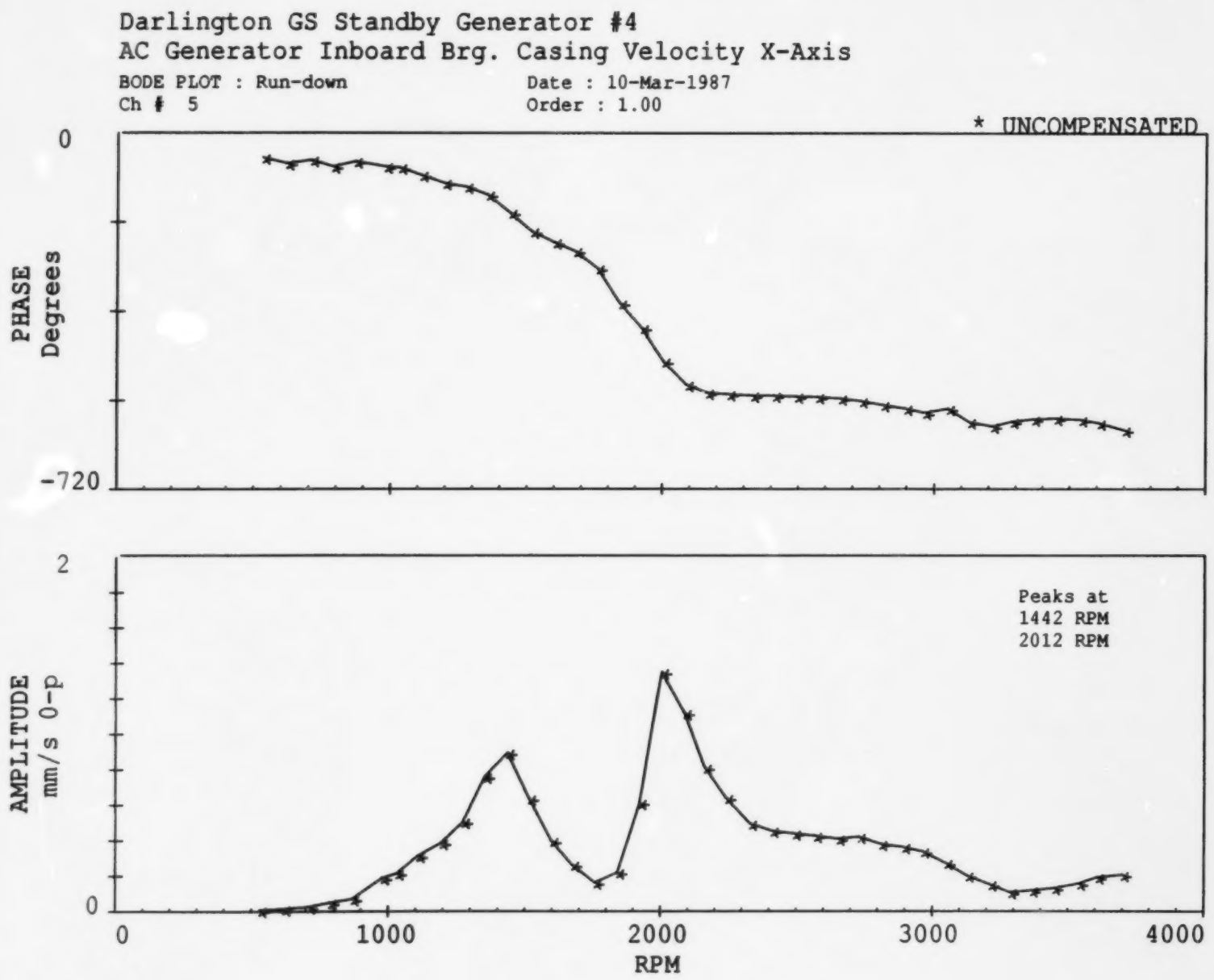
Darlington GS Standby Generator #4
AC Generator Inboard Brg. Casing Velocity X-Axis
BODE PLOT : Run-down
Ch # 5
Date : 10-Mar-1987
Order : 1.00
* UNCOMPENSATED
0
PHASE
Degrees
-720
2
AMPLITUDE
mm/s 0-p
0
Peaks at
1442 RPM
2012 RPM
0
1000
2000
3000
4000
RPM

FIGURE 170

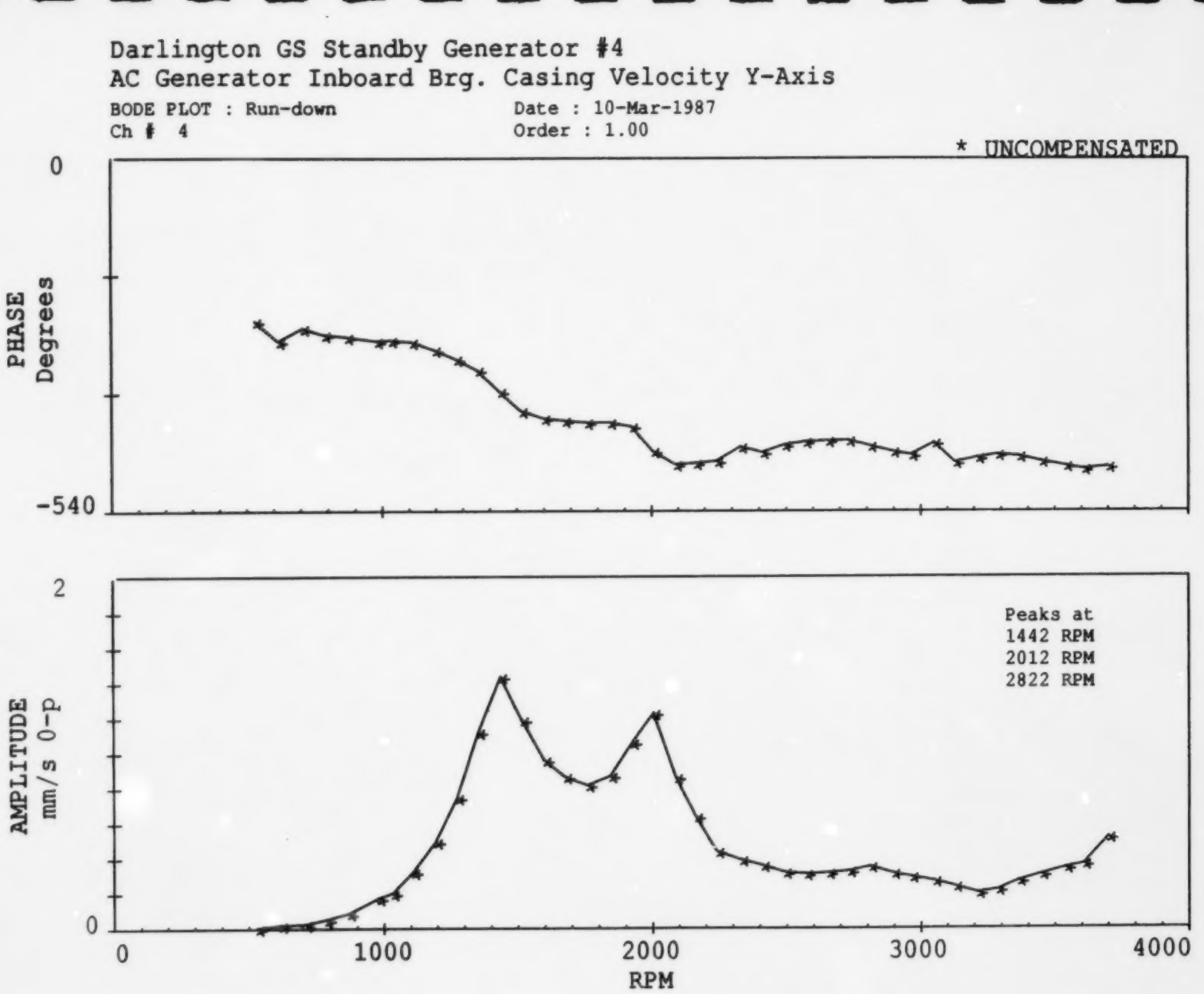
Darlington GS Standby Generator #4
AC Generator Inboard Brg. Casing Velocity Y-Axis
BODE PLOT : Run-down
Ch # 4
Date : 10-Mar-1987
Order : 1.00
* UNCOMPENSATED
0
PHASE
Degrees
-540
2
AMPLITUDE
mm/s 0-p
0
Peaks at
1442 RPM
2012 RPM
2822 RPM
0
1000
2000
3000
4000
RPM

FIGURE 171

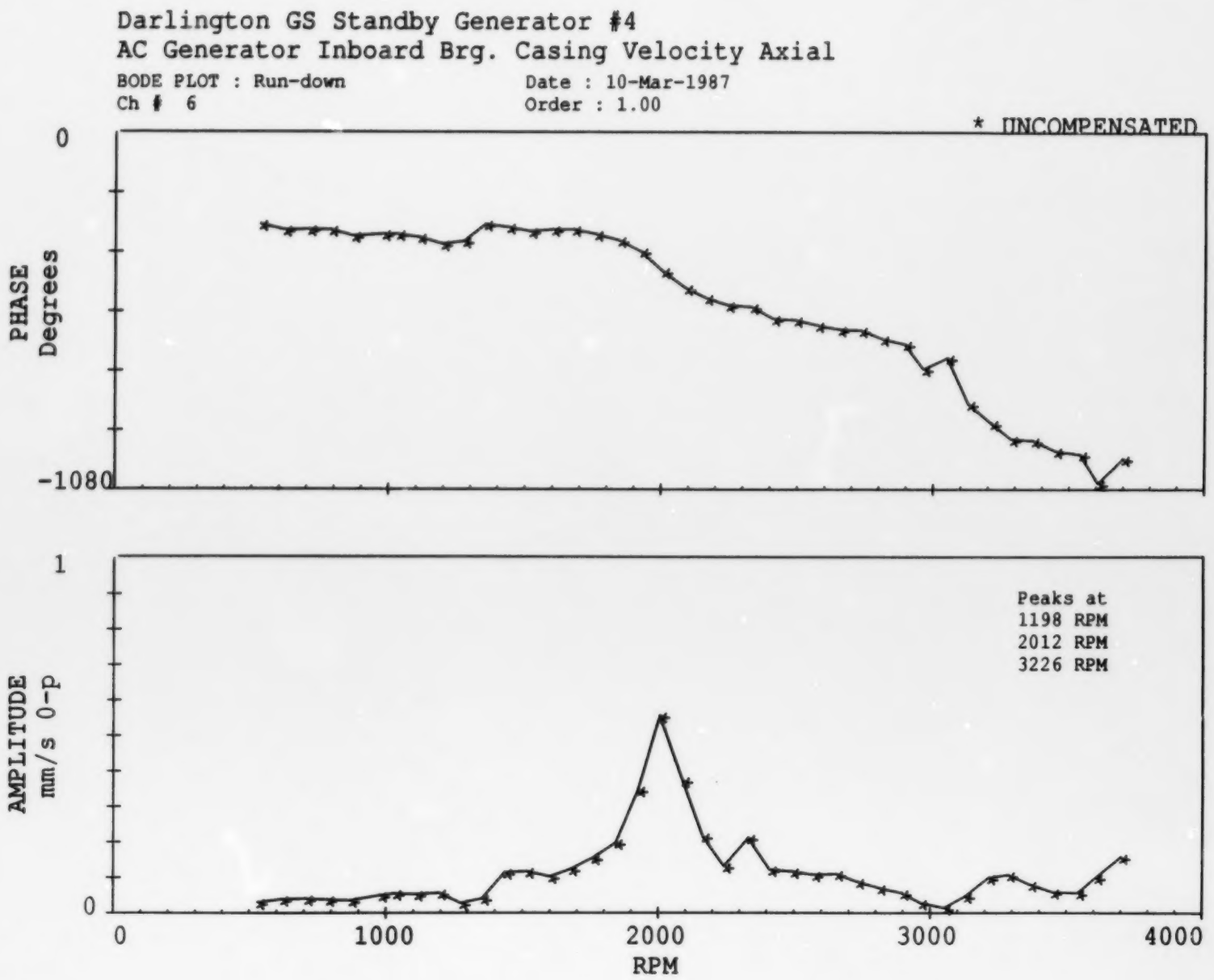
Darlington GS Standby Generator #4
AC Generator Inboard Brg. Casing Velocity Axial
BODE PLOT : Run-down
Ch # 6
Date : 10-Mar-1987
Order : 1.00
* UNCOMPENSATED
0
PHASE
Degrees
-1080
1
AMPLITUDE
mm/s 0-p
0
Peaks at
1198 RPM
2012 RPM
3226 RPM
0
1000
2000
3000
4000
RPM

FIGURE 172

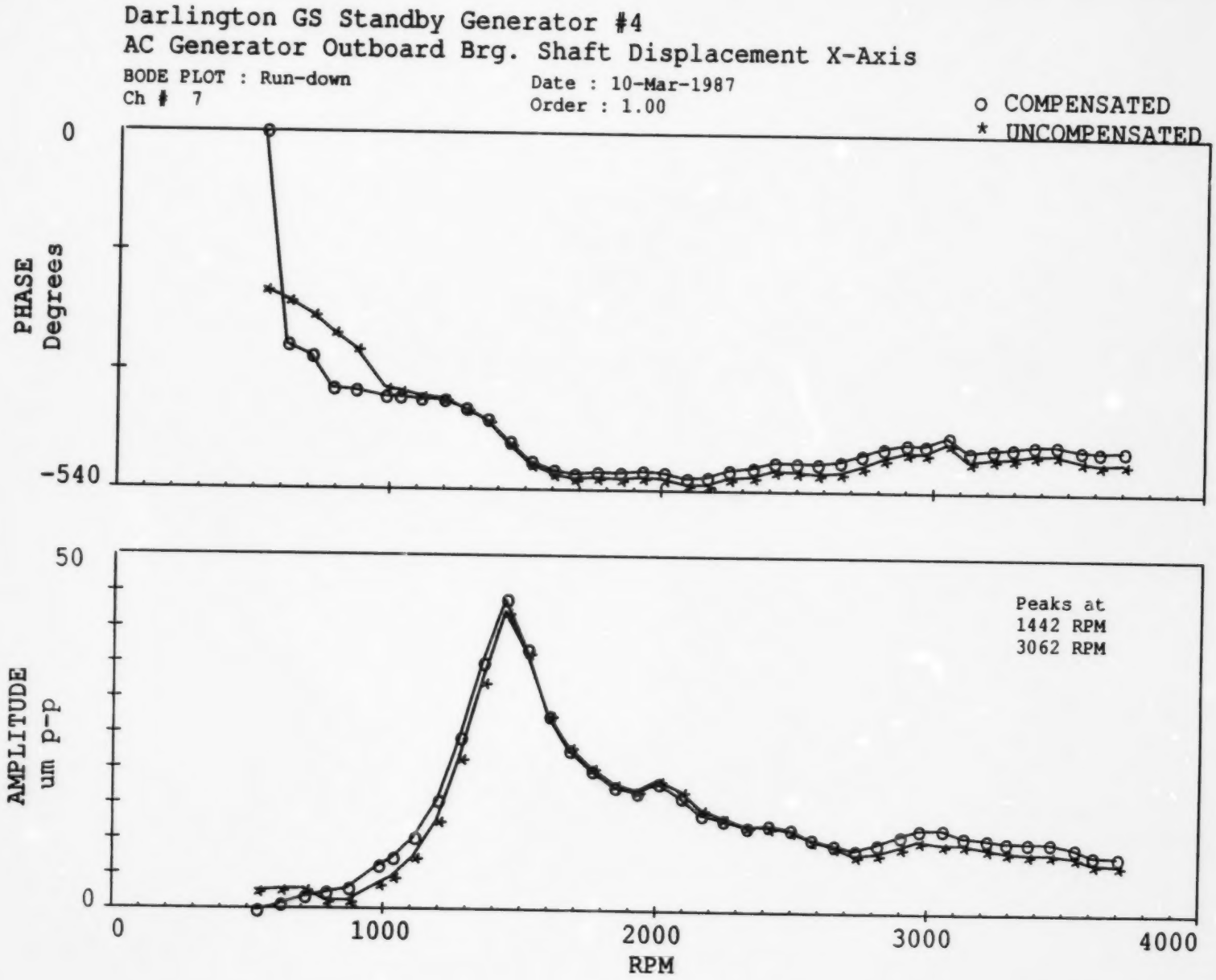
Darlington GS Standby Generator #4
AC Generator Outboard Brg. Shaft Displacement X-Axis
BODE PLOT : Run-down
Ch # 7
Date : 10-Mar-1987
Order : 1.00
o COMPENSATED
* UNCOMPENSATED
0
-540
PHASE
Degrees
50
0
AMPLITUDE
um p-p
Peaks at
1442 RPM
3062 RPM
0
1000
2000
3000
4000
RPM

FIGURE 173

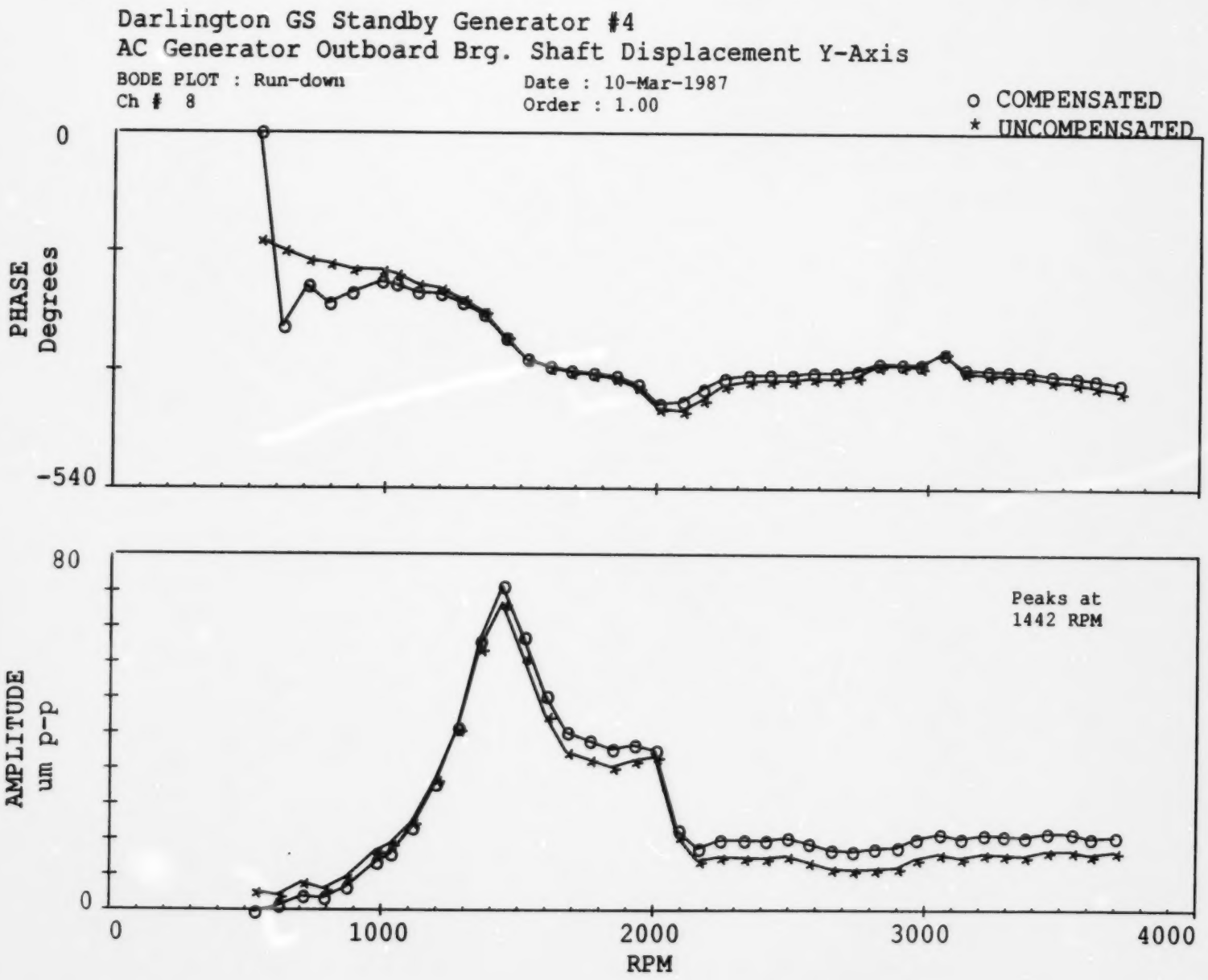

FIGURE 174

89-6

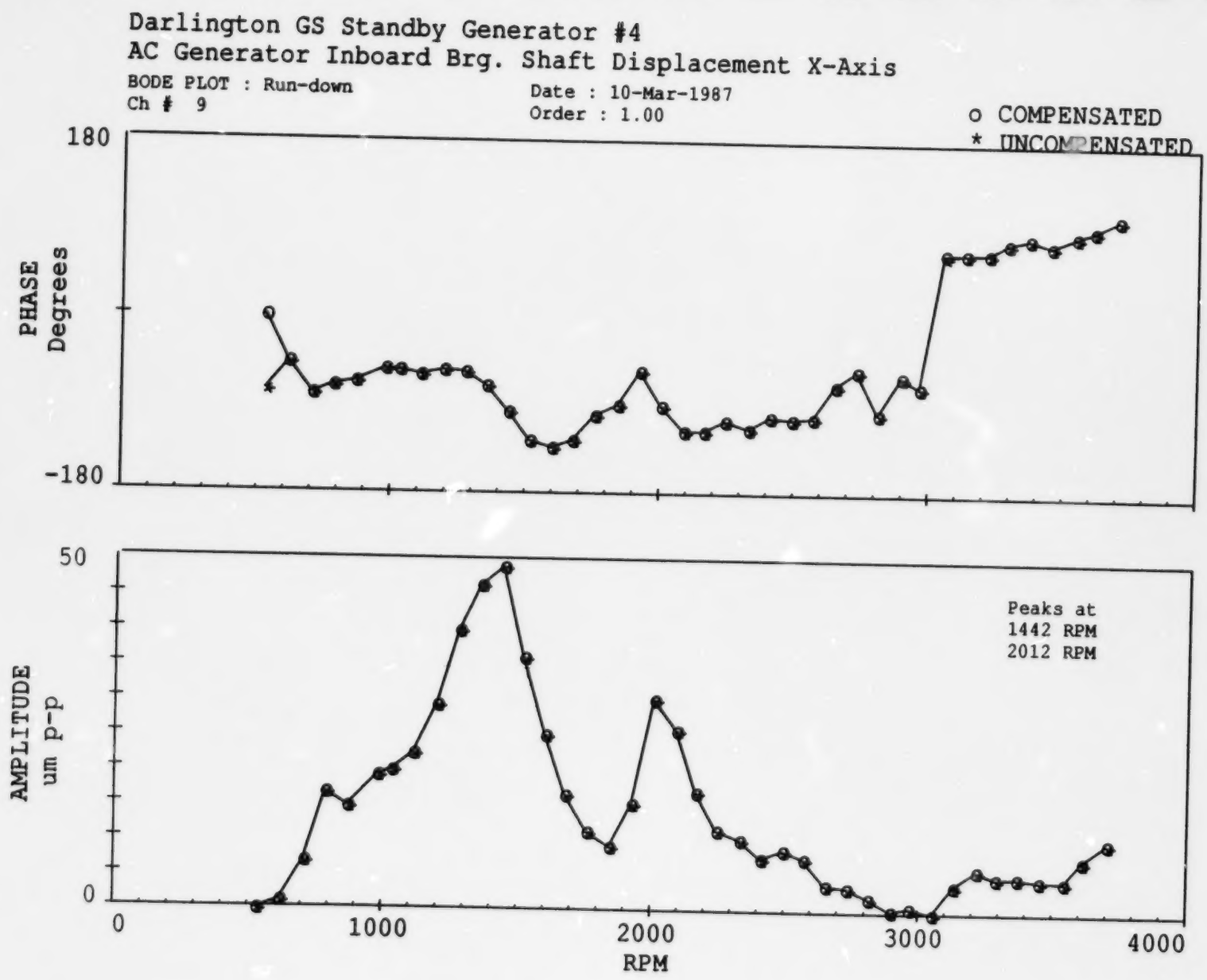
Darlington GS Standby Generator #4
AC Generator Inboard Brg. Shaft Displacement X-Axis
BODE PLOT : Run-down
Ch # 9
Date : 10-Mar-1987
Order : 1.00
o COMPENSATED
* UNCOMPENSATED
180
-180
PHASE
Degrees
50
0
AMPLITUDE
um p-p
Peaks at
1442 RPM
2012 RPM
0
1000
2000
3000
4000
RPM

FIGURE 175

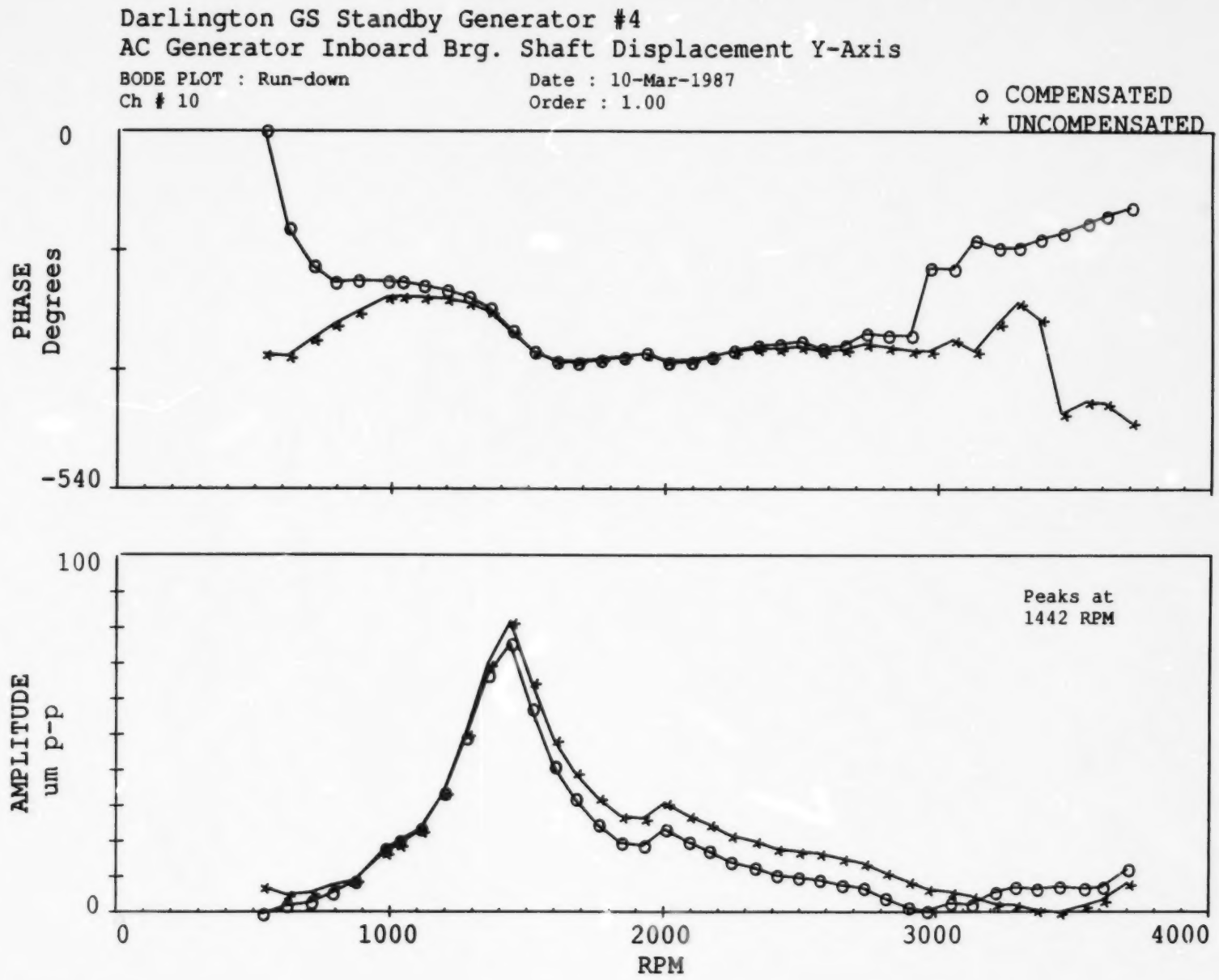

FIGURE 176

89-6

Darlington GS Standby Generator #4
Turbine Inboard Brg. Casing Velocity X-Axis

BODE PLOT : Run-down
Ch # 2

Date : 10-Mar-1987
Order : 1.00

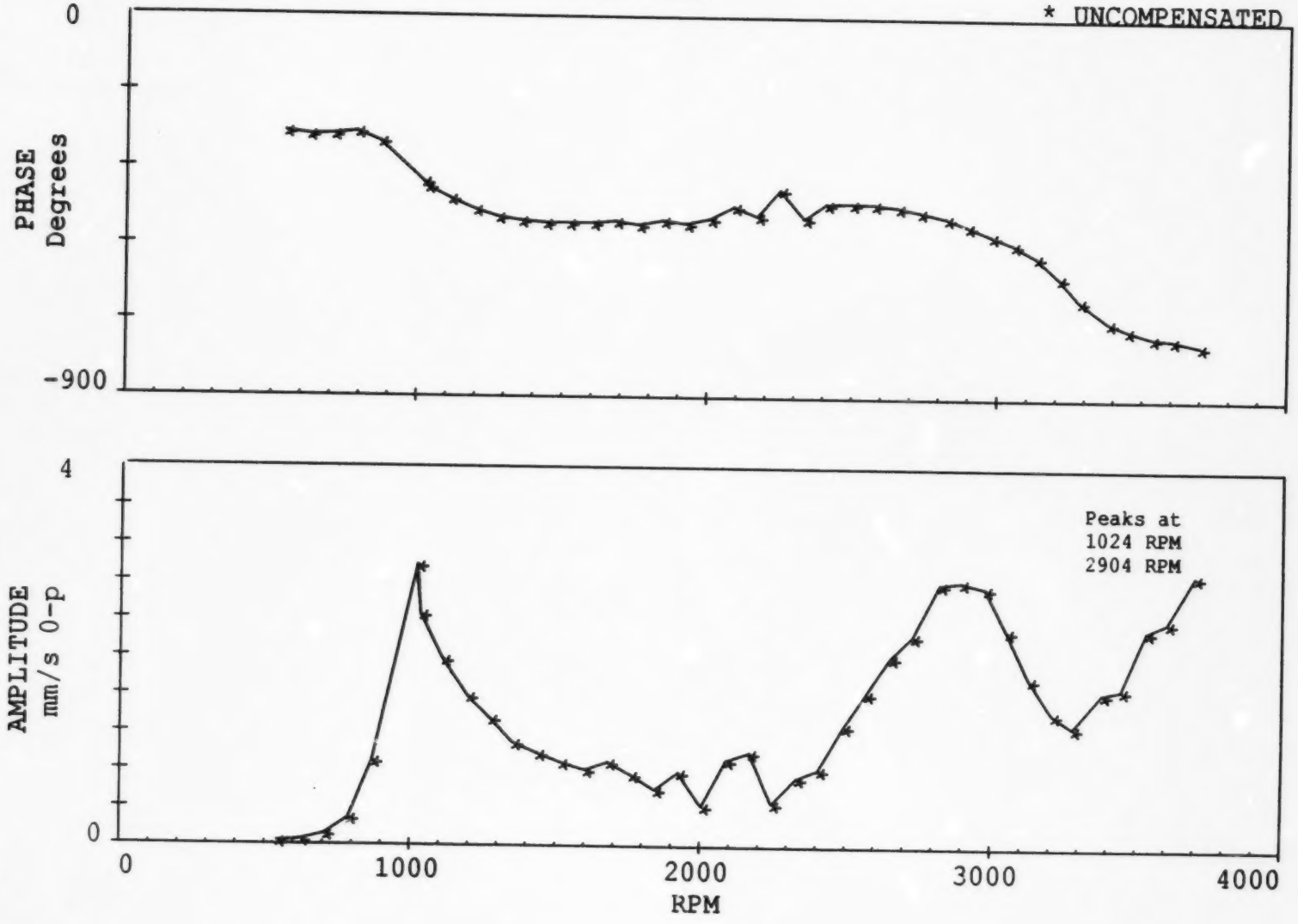

FIGURE 177

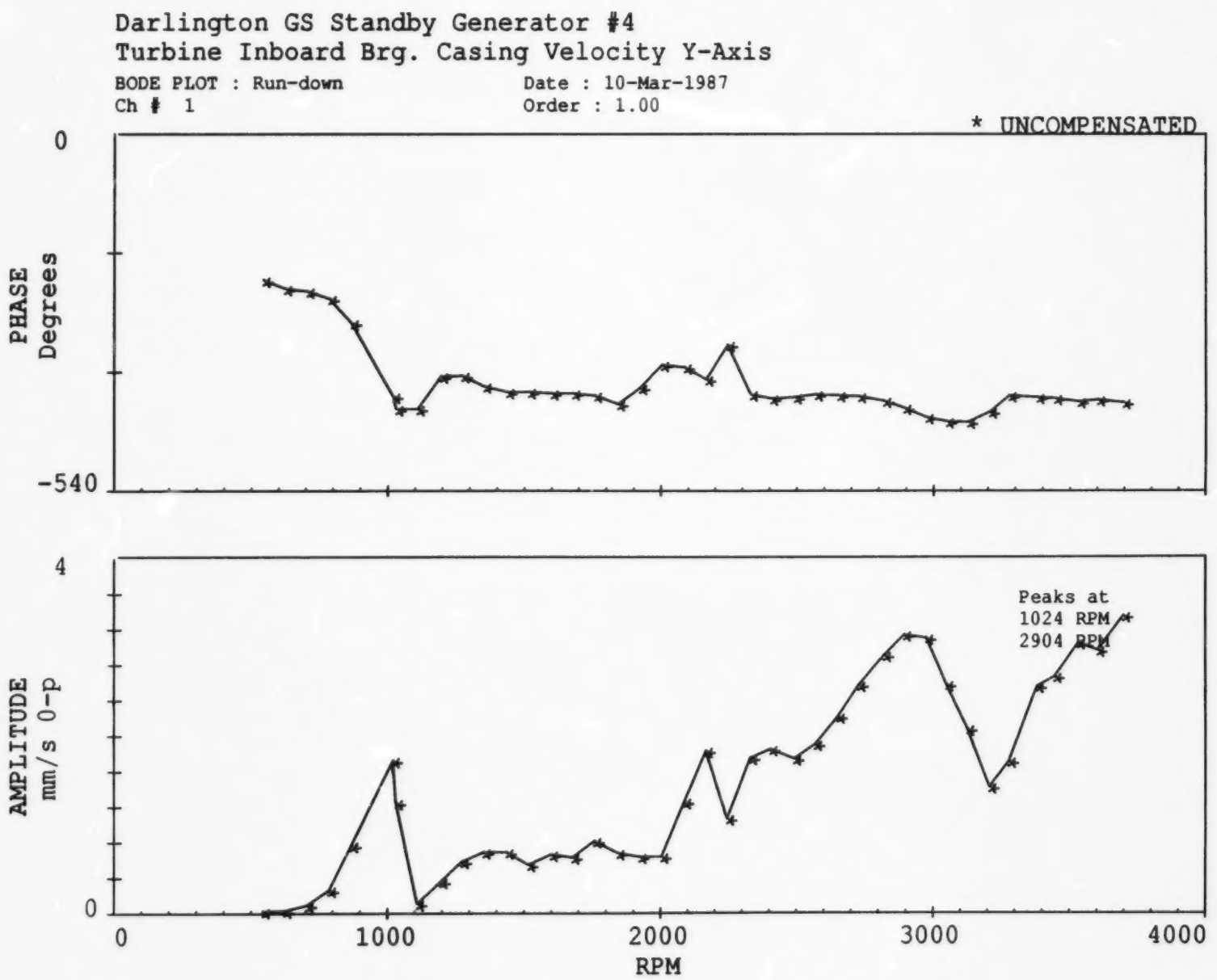
Darlington GS Standby Generator #4
Turbine Inboard Brg. Casing Velocity Y-Axis
BODE PLOT : Run-down
Ch # 1
Date : 10-Mar-1987
Order : 1.00
* UNCOMPENSATED
0
PHASE
Degrees
-540
4
AMPLITUDE
mm/s 0-p
0
Peaks at
1024 RPM
2904 RPM
0
1000
2000
3000
4000
RPM

FIGURE 178

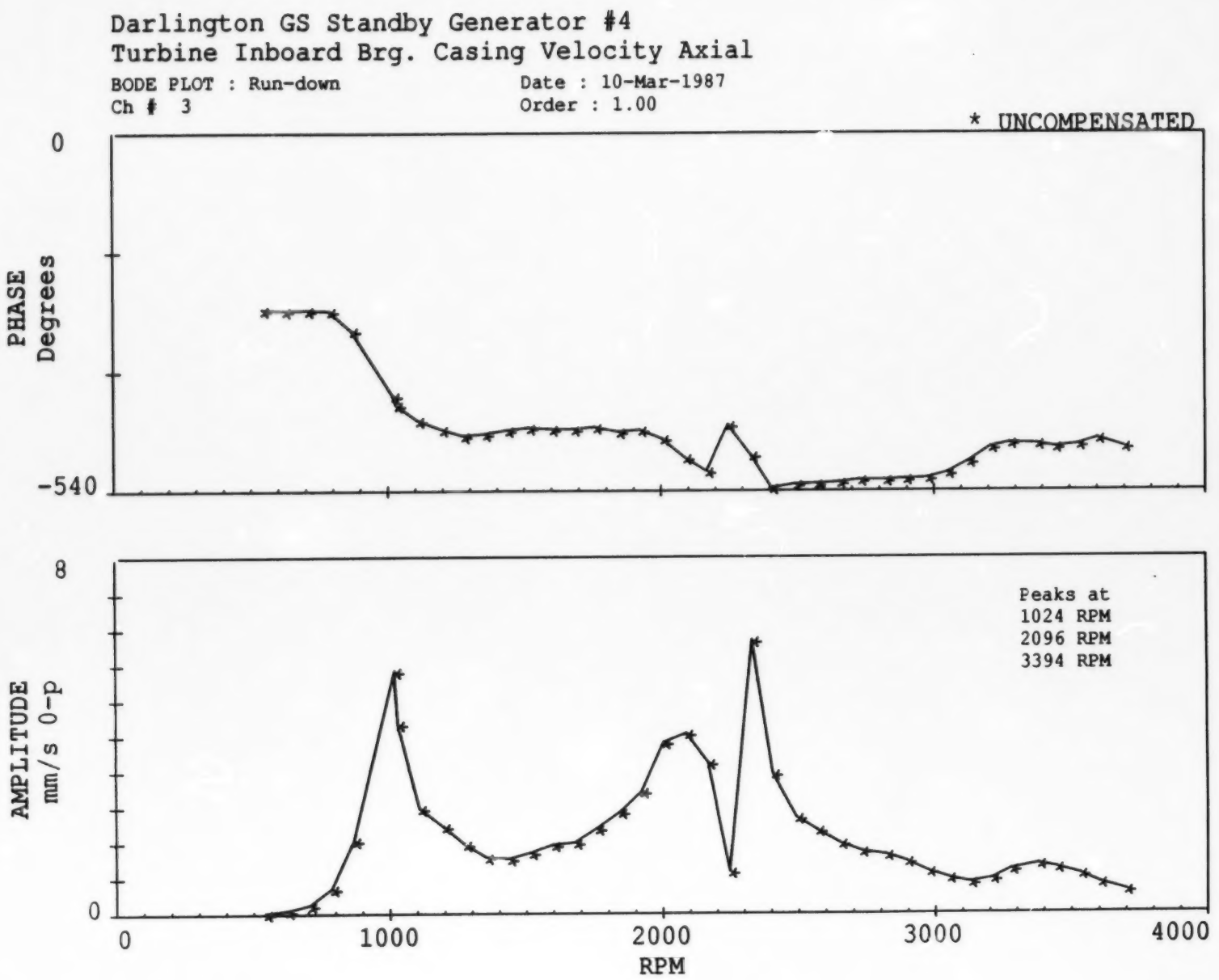
Darlington GS Standby Generator #4
Turbine Inboard Brg. Casing Velocity Axial
BODE PLOT : Run-down
Ch # 3
Date : 10-Mar-1987
Order : 1.00
* UNCOMPENSATED
0
PHASE
Degrees
-540
8
AMPLITUDE
mm/s 0-p
0
Peaks at
1024 RPM
2096 RPM
3394 RPM
0
1000
2000
3000
4000
RPM

FIGURE 179

Darlington GS Standby Generator #4
Turbine Outboard Brg. Casing Velocity Horiz.

BODE PLOT : Run-down
Ch # 5

Date : 10-Mar-1987
Order : 1.00

* UNCOMPENSATED

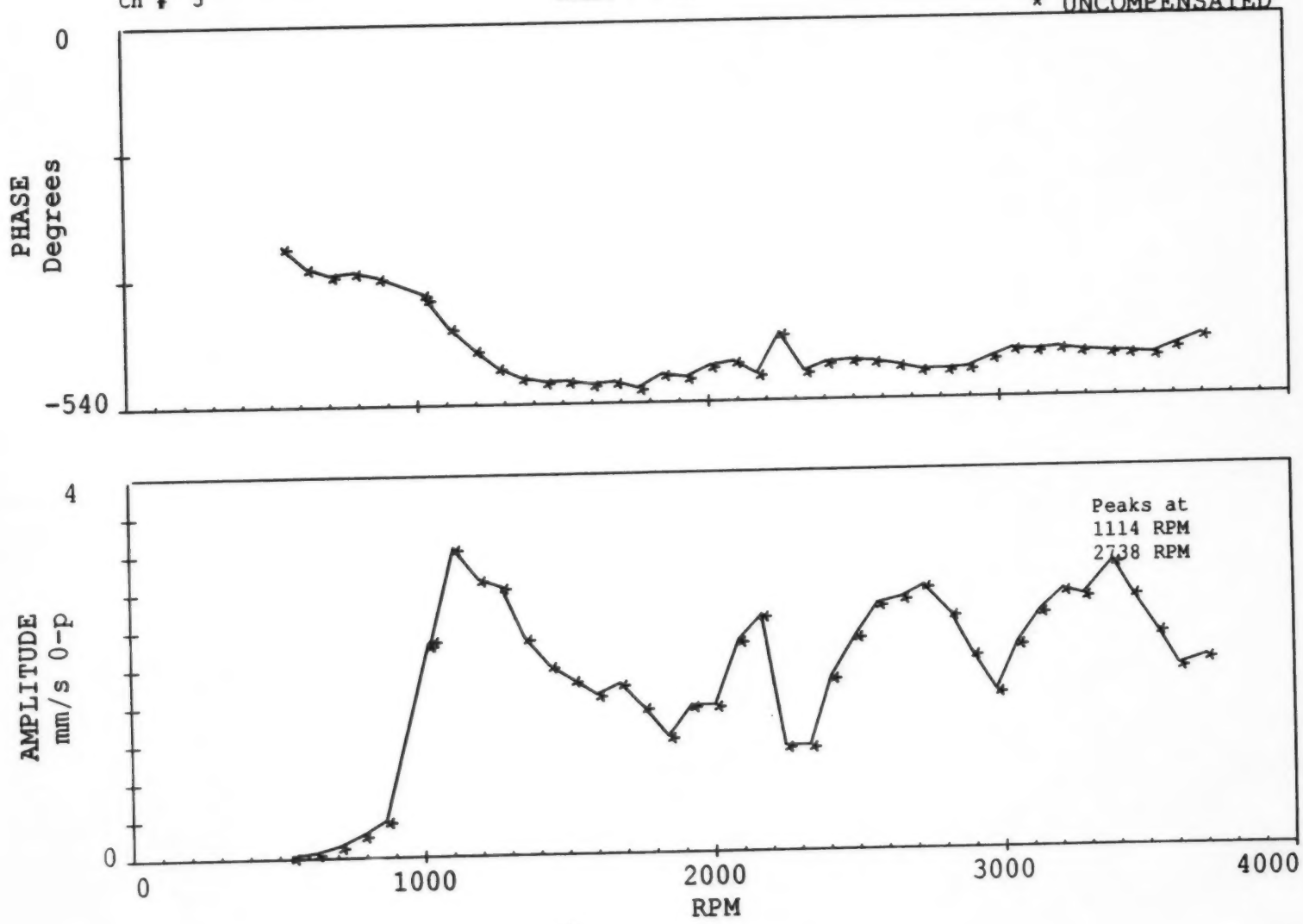

FIGURE 180

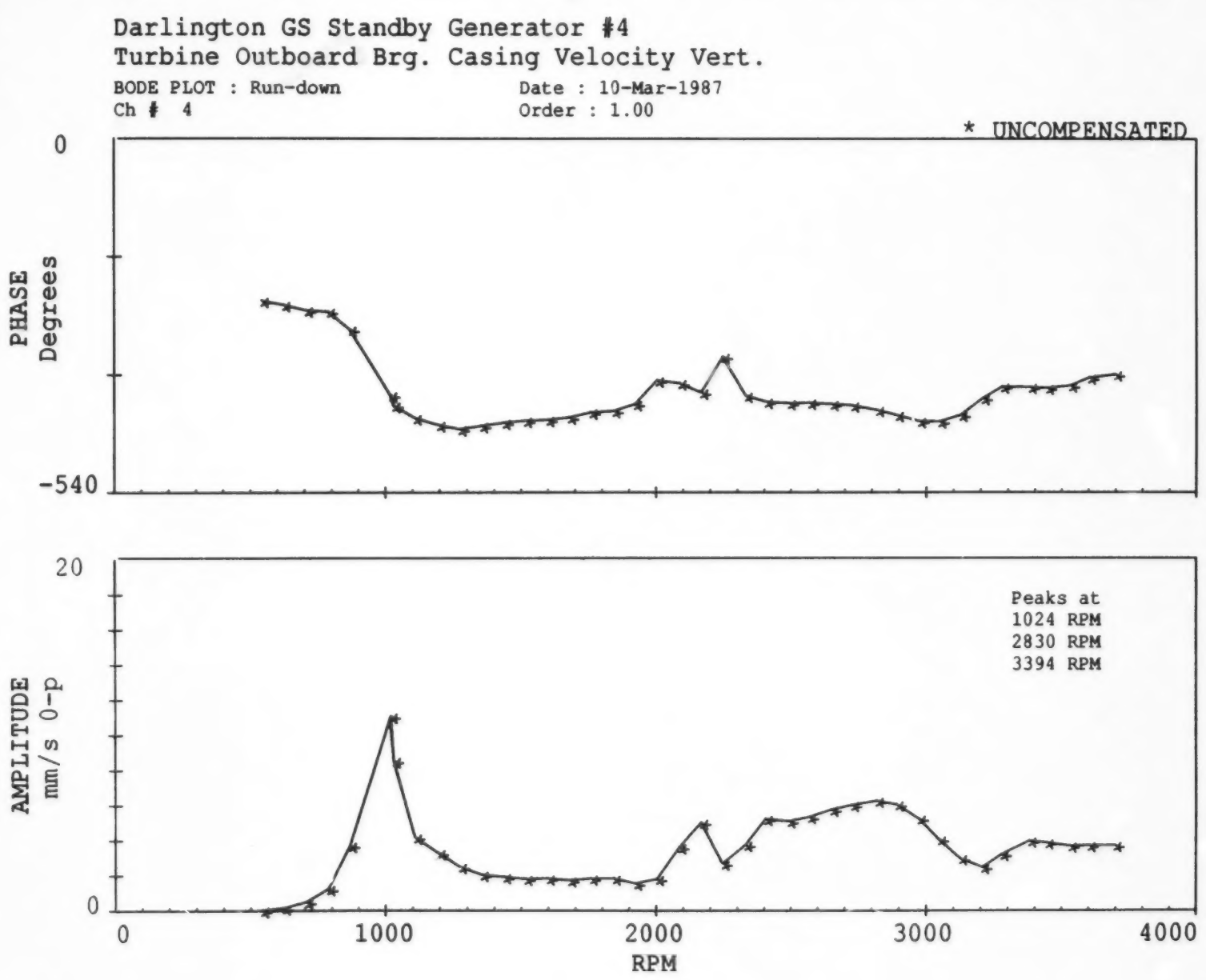
Darlington GS Standby Generator #4
Turbine Outboard Brg. Casing Velocity Vert.
BODE PLOT : Run-down
Ch # 4
Date : 10-Mar-1987
Order : 1.00
* UNCOMPENSATED
0
PHASE
Degrees
-540
20
AMPLITUDE
mm/s 0-p
0
Peaks at
1024 RPM
2830 RPM
3394 RPM
0
1000
2000
3000
4000
RPM

FIGURE 181

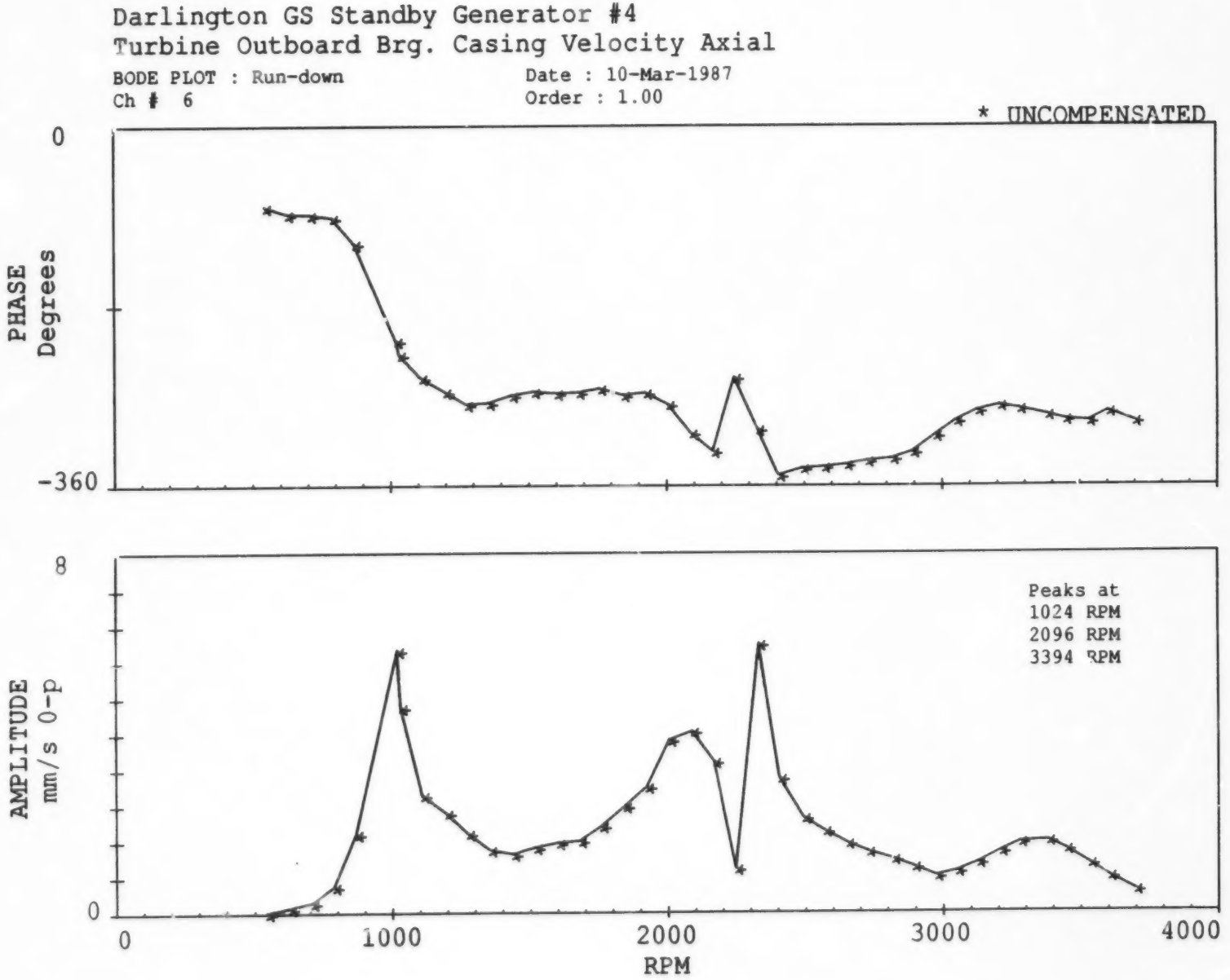
Darlington GS Standby Generator #4
Turbine Outboard Brg. Casing Velocity Axial
BODE PLOT : Run-down
Ch # 6
Date : 10-Mar-1987
Order : 1.00
* UNCOMPENSATED
0
PHASE
Degrees
-360
8
AMPLITUDE
mm/s 0-p
0
Peaks at
1024 RPM
2096 RPM
3394 RPM
0
1000
2000
3000
4000
RPM

FIGURE 182

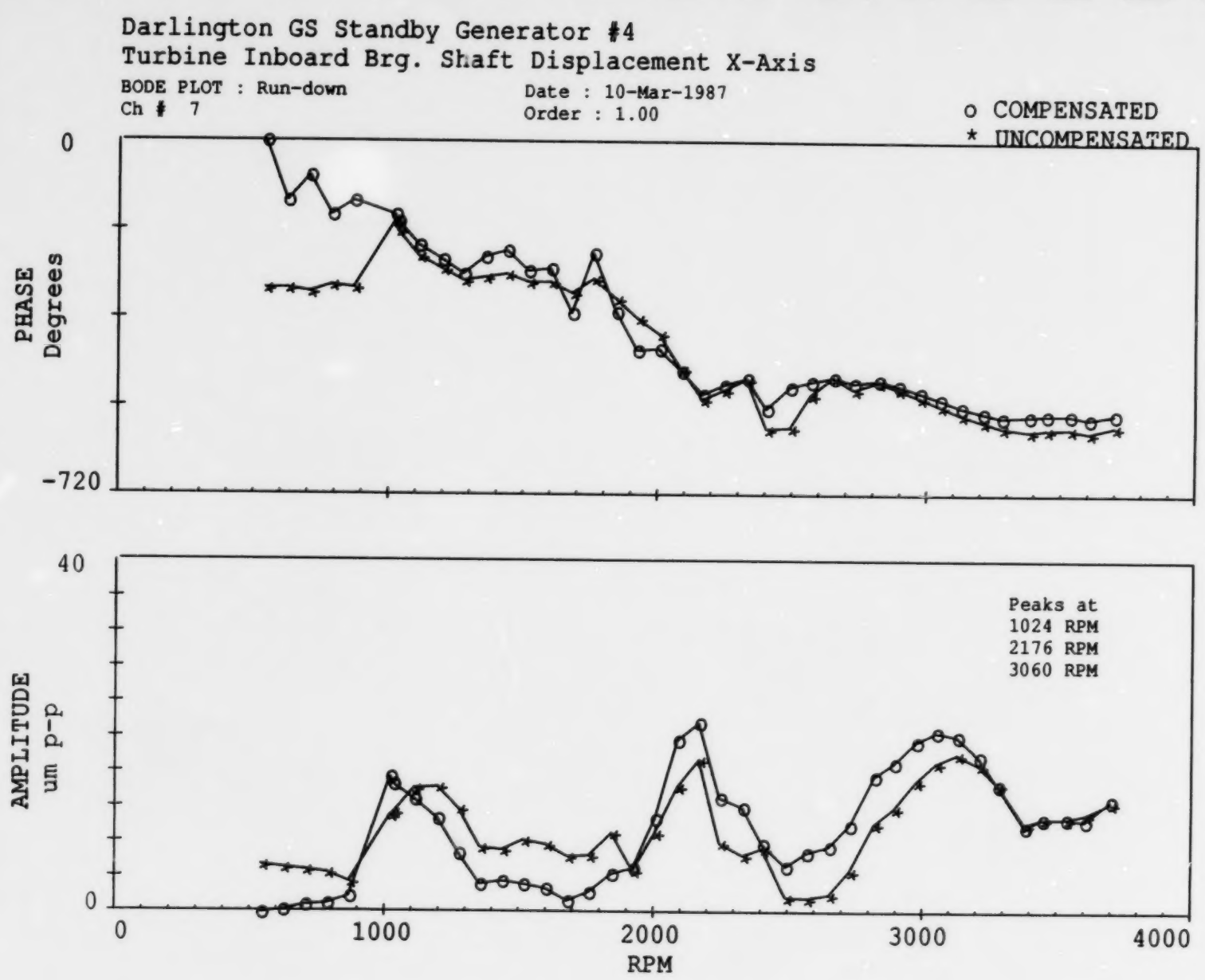
Darlington GS Standby Generator #4
Turbine Inboard Brg. Shaft Displacement X-Axis
BODE PLOT : Run-down
Ch # 7
Date : 10-Mar-1987
Order : 1.00
o COMPENSATED
* UNCOMPENSATED
PHASE
Degrees
0
-720
AMPLITUDE
um p-p
40
0
Peaks at
1024 RPM
2176 RPM
3060 RPM
0
1000
2000
3000
4000
RPM

FIGURE 183

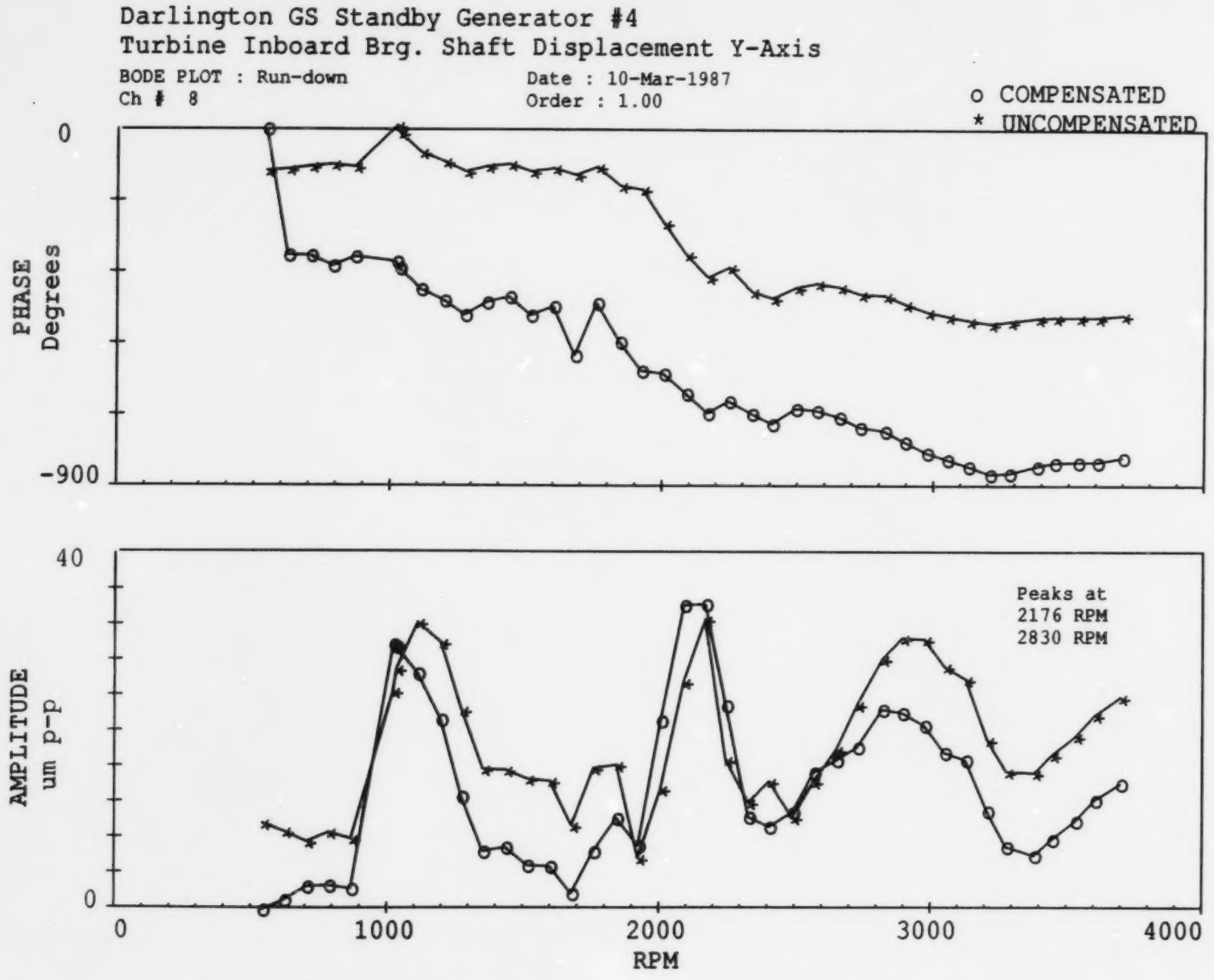

FIGURE 184

89-6

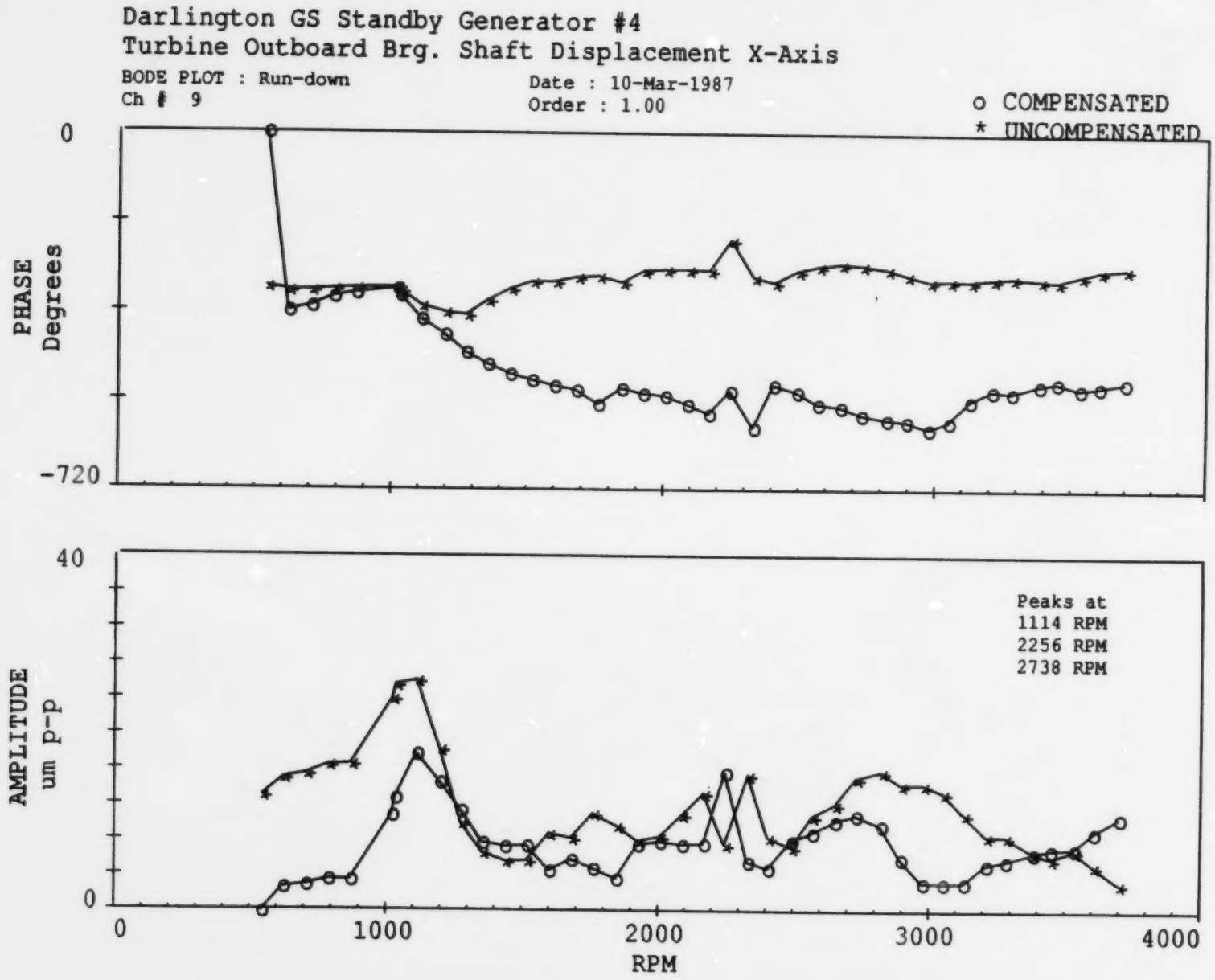
Darlington GS Standby Generator #4
Turbine Outboard Brg. Shaft Displacement X-Axis
BODE PLOT : Run-down
Ch # 9
Date : 10-Mar-1987
Order : 1.00
o COMPENSATED
* UNCOMPENSATED
0
PHASE
Degrees
-720
40
AMPLITUDE
um p-p
0
Peaks at
1114 RPM
2256 RPM
2738 RPM
0
1000
2000
3000
4000
RPM

FIGURE 185

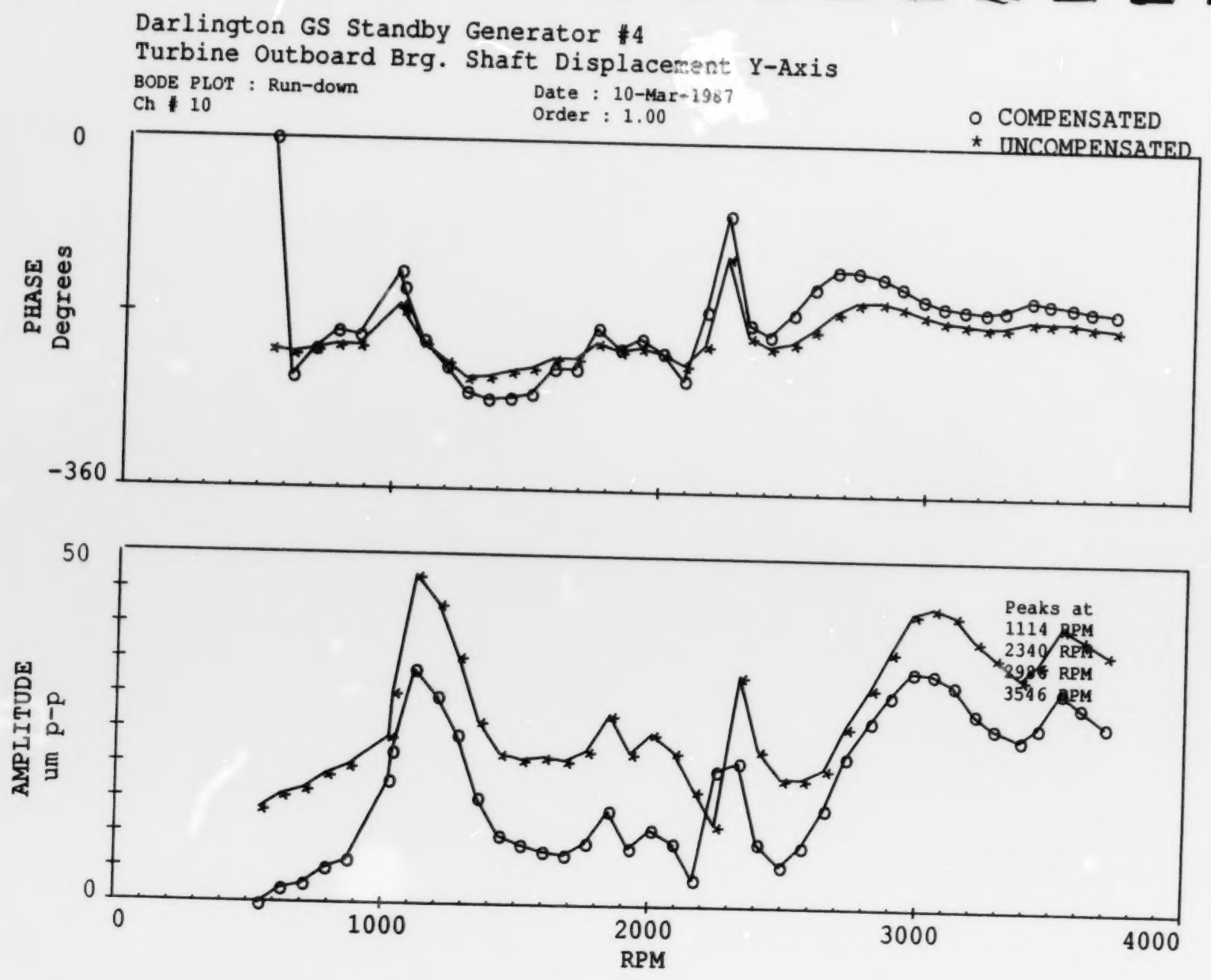
Darlington GS Standby Generator #4
Turbine Outboard Brg. Shaft Displacement Y-Axis
BODE PLOT : Run-down
Ch # 10
Date : 10-Mar-1987
Order : 1.00
o COMPENSATED
* UNCOMPENSATED
0
-360
PHASE
Degrees
50
0
AMPLITUDE
um p-p
Peaks at
1114 RPM
2340 RPM
2926 RPM
3546 RPM
0
1000
2000
3000
4000
RPM

FIGURE 186

Darlington GS Standby Generator #4
AC Generator

RPM SPECTRAL MAP : Run-down
Date : 10-Mar-1987

Ch # 2 Outboard Brg. Casing Velocity X-Axis

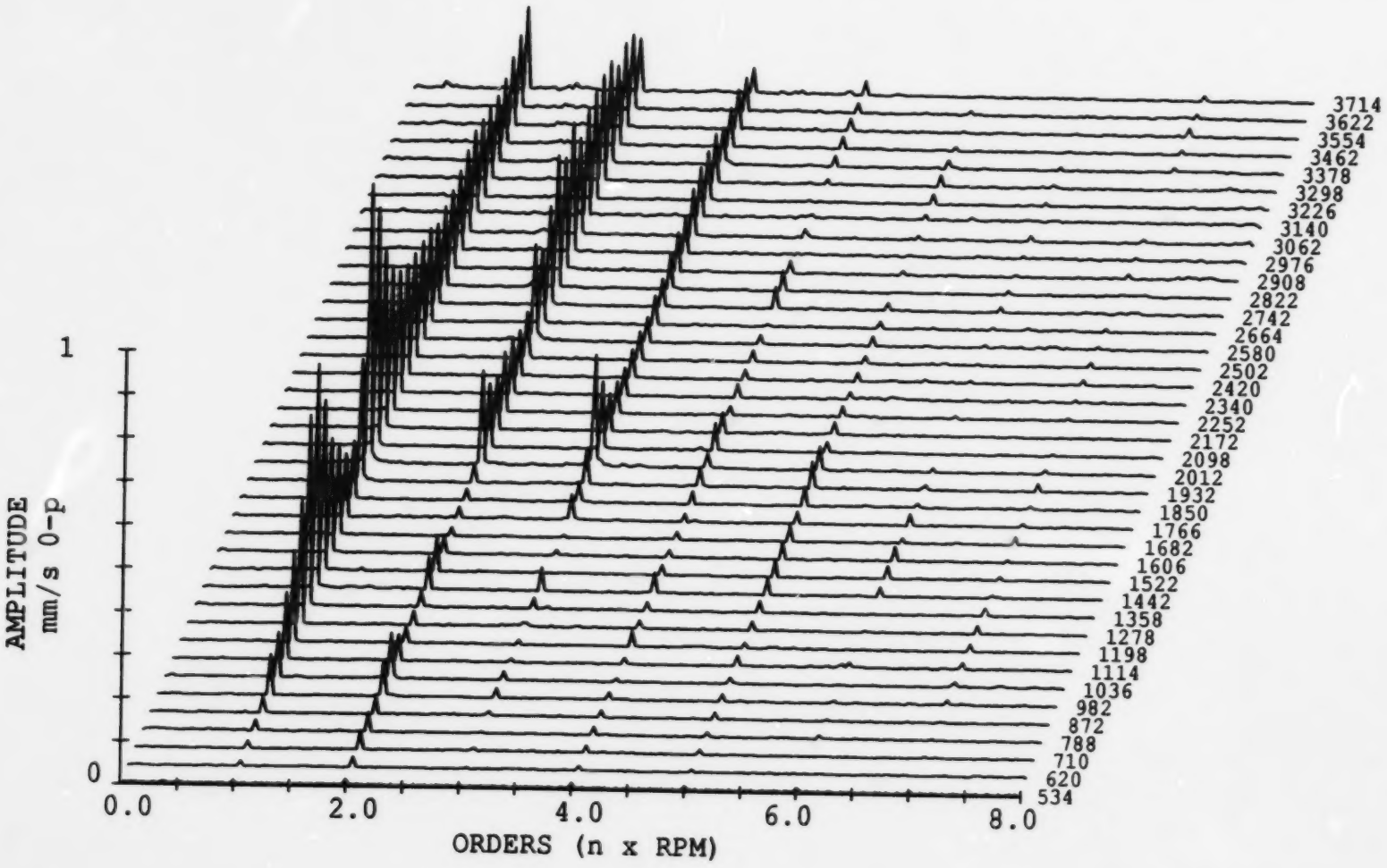

FIGURE 187

89-6

Darlington GS Standby Generator #4
AC Generator

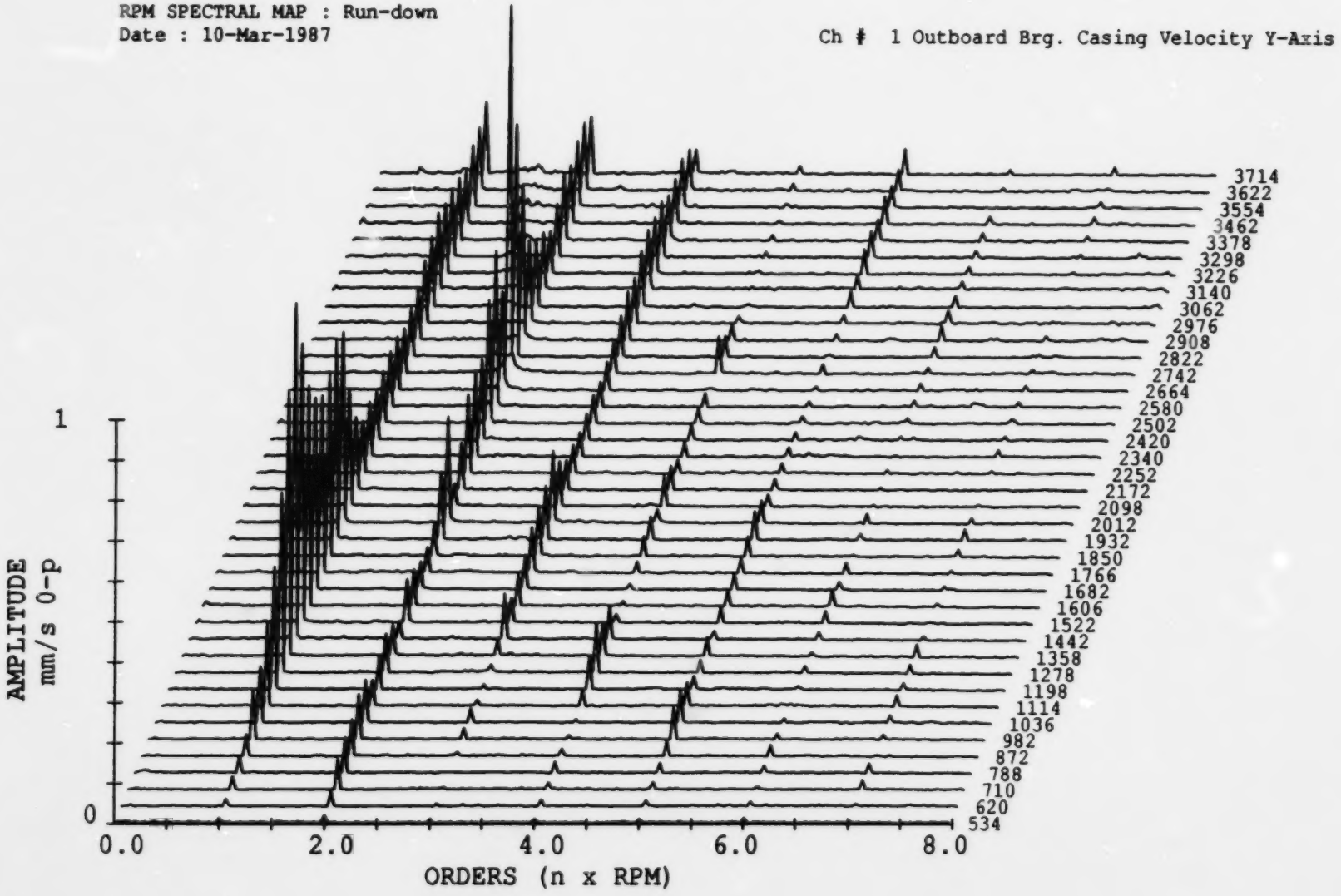

FIGURE 188

Darlington GS Standby Generator #4
AC Generator

RPM SPECTRAL MAP : Run-down
Date : 10-Mar-1987

Ch # 3 Outboard Brg. Casing Velocity Axial

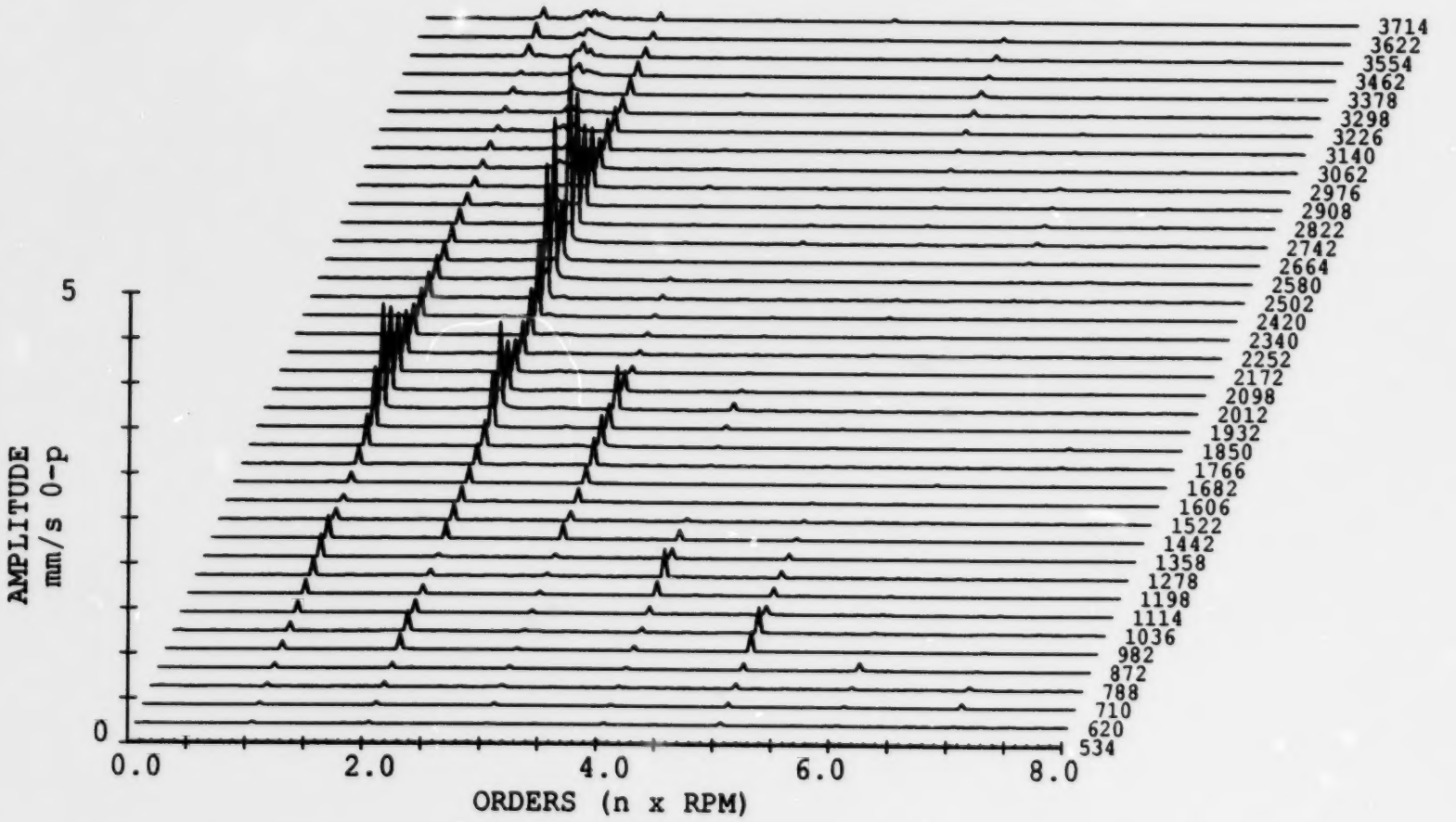

FIGURE 189

Darlington GS Standby Generator #4
AC Generator

RPM SPECTRAL MAP : Run-down
Date : 10-Mar-1987

Ch # 5 Inboard Brg. Casing Velocity X-Axis

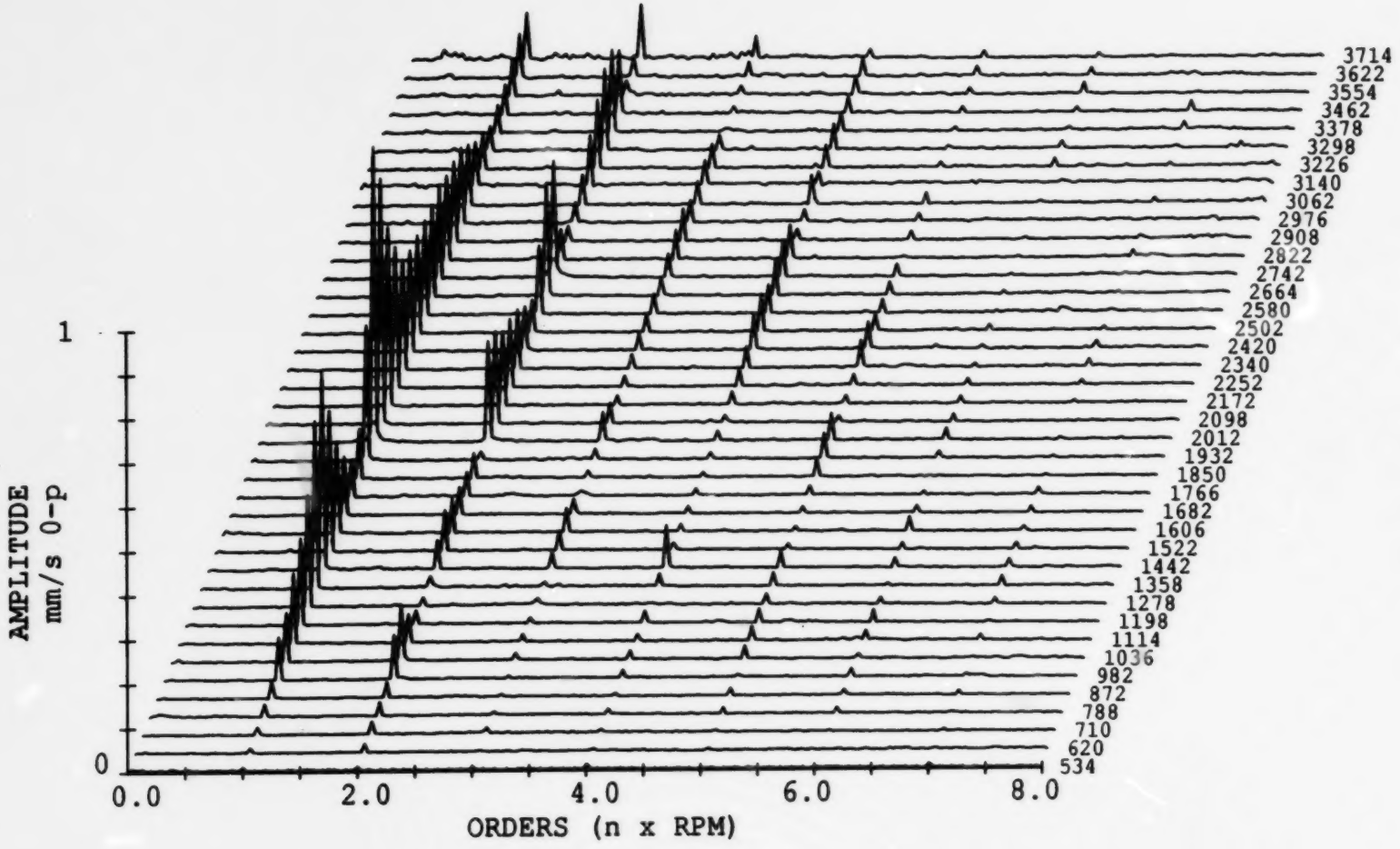

FIGURE 190

Darlington GS Standby Generator #4
AC Generator

RPM SPECTRAL MAP : Run-down
Date : 10-Mar-1987

Ch # 4 Inboard Brg. Casing Velocity Y-Axis

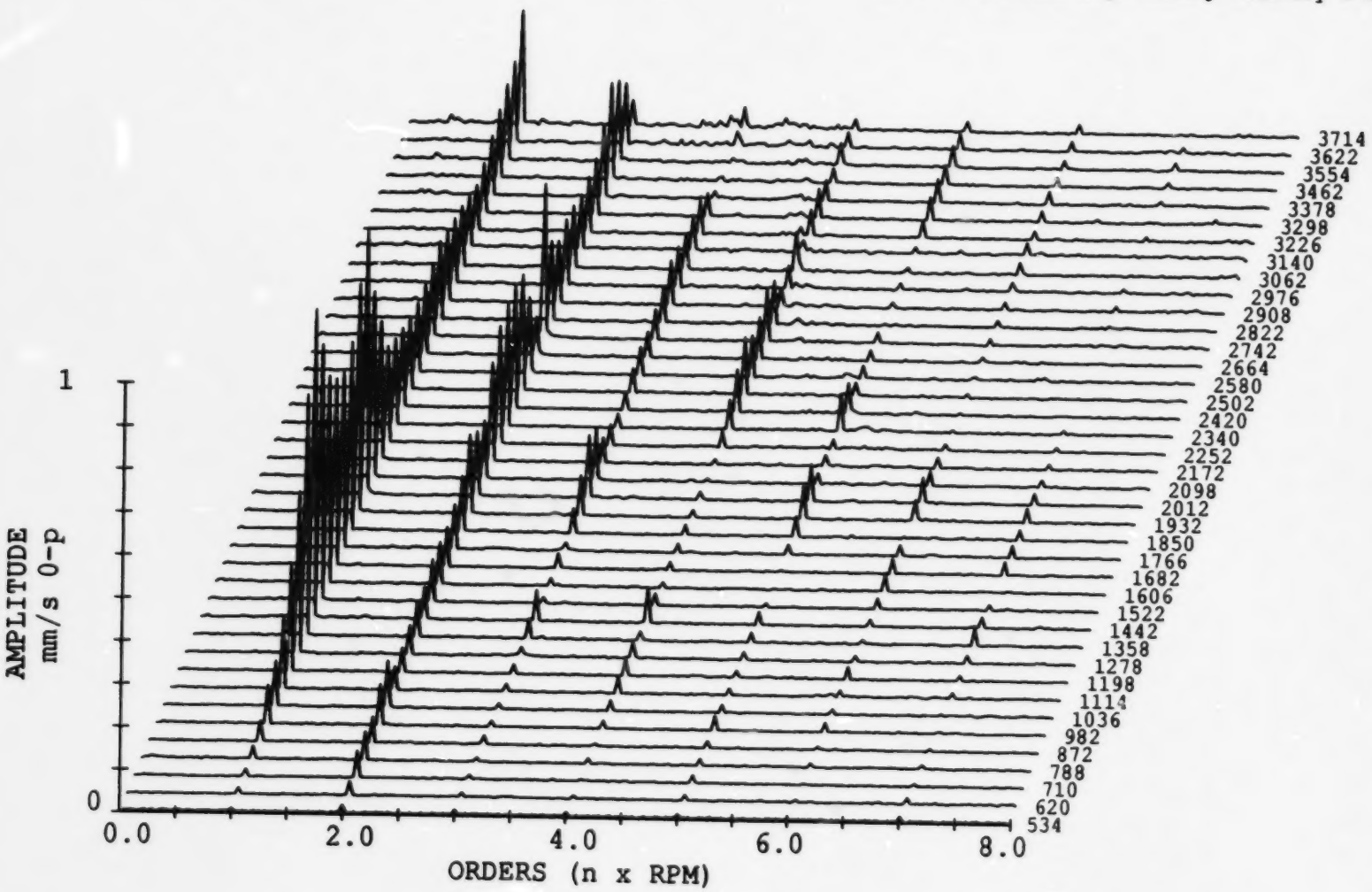

FIGURE 191

89-6

Darlington GS Standby Generator #4
AC Generator

RPM SPECTRAL MAP : Run-down
Date : 10-Mar-1987

Ch # 6 Inboard Brg. Casing Velocity Axial

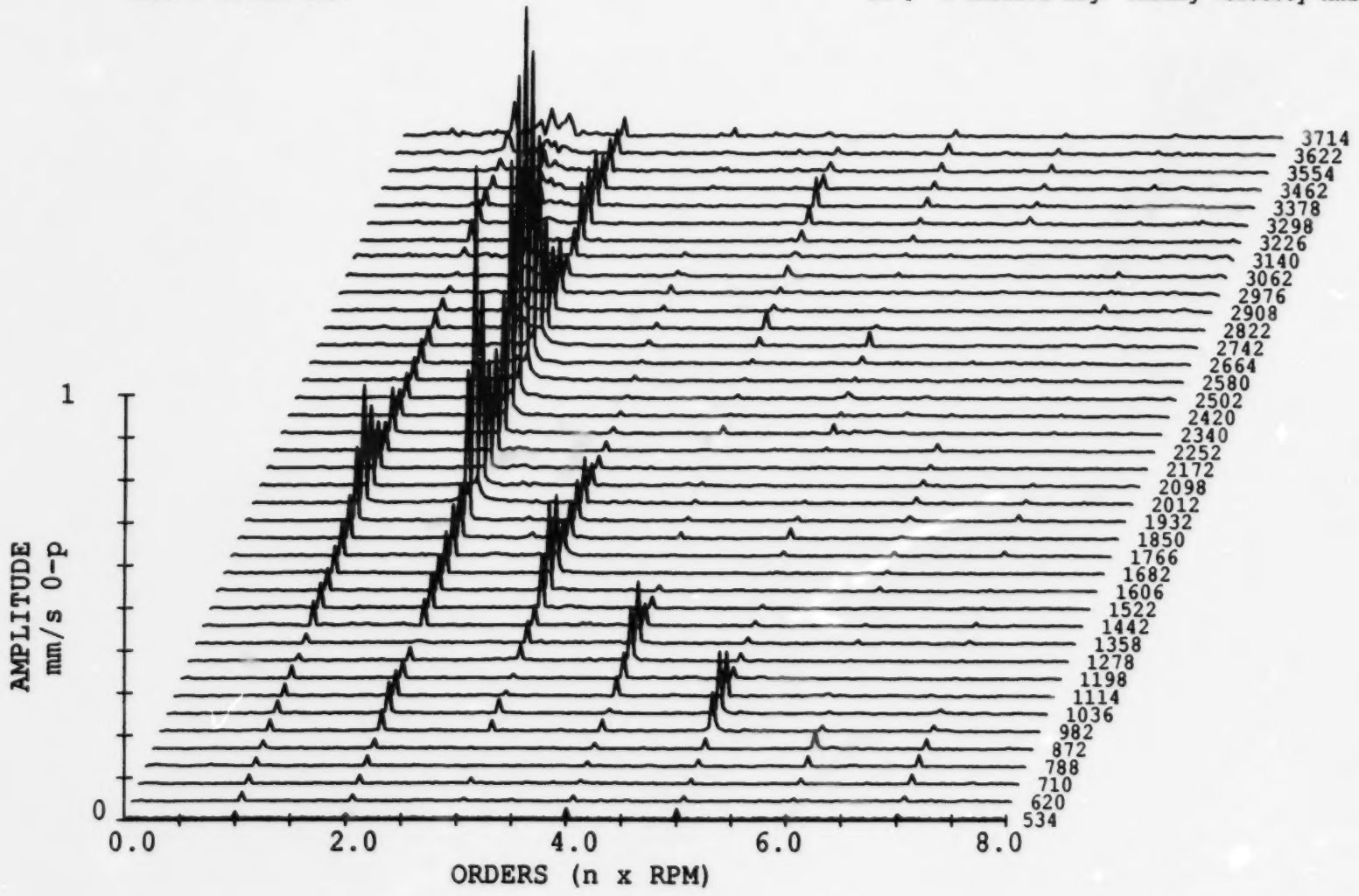

FIGURE 192

89-6

Darlington GS Standby Generator #4
AC Generator

RPM SPECTRAL MAP : Run-down
Date : 10-Mar-1987

Ch # 7 Outboard Brg. Shaft Displacement X-Axis

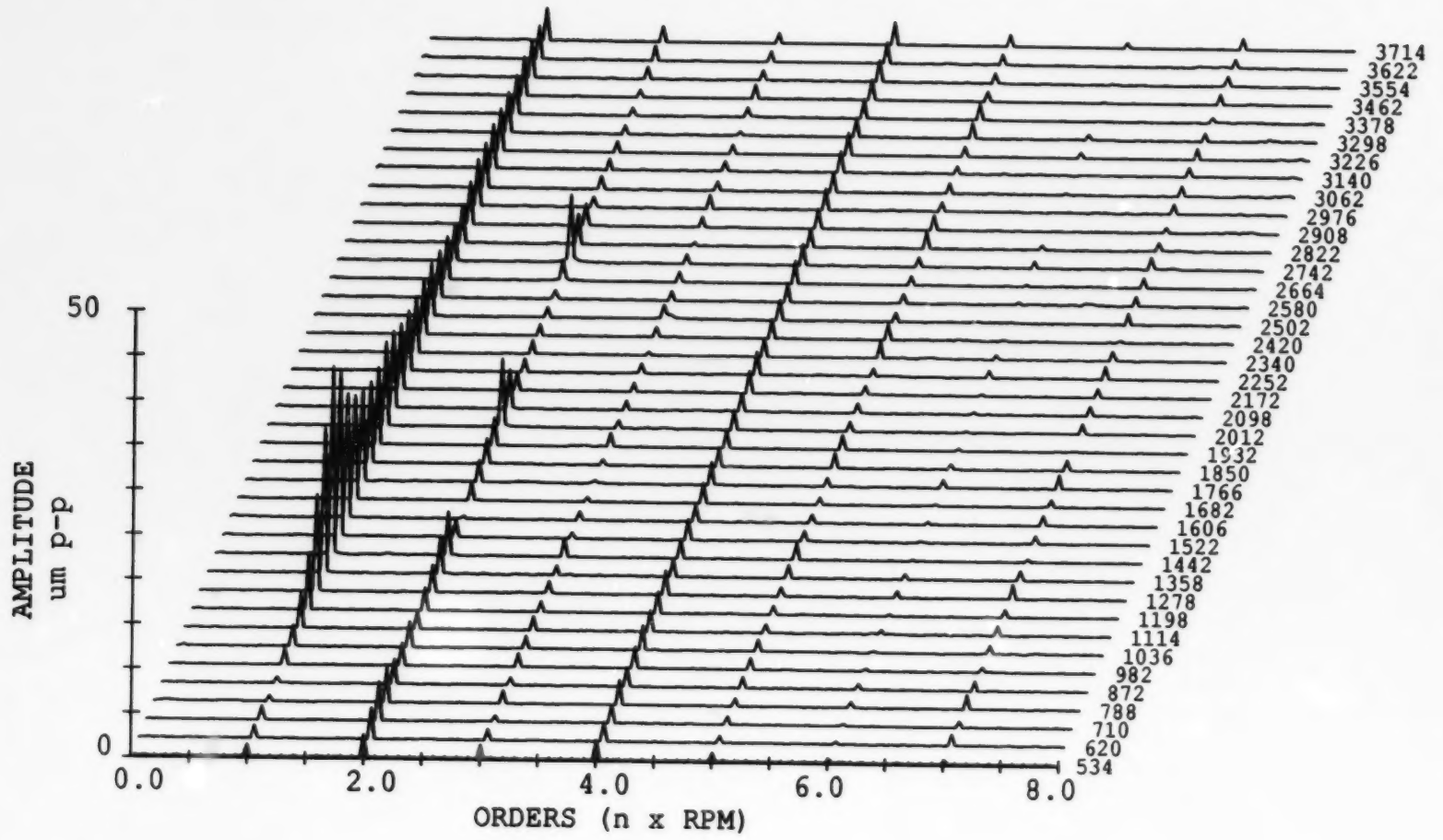

FIGURE 193

Darlington GS Standby Generator #4
AC Generator

RPM SPECTRAL MAP : Run-down
Date : 10-Mar-1987

Ch # 8 Outboard Brg. Shaft Displacement Y-Axis

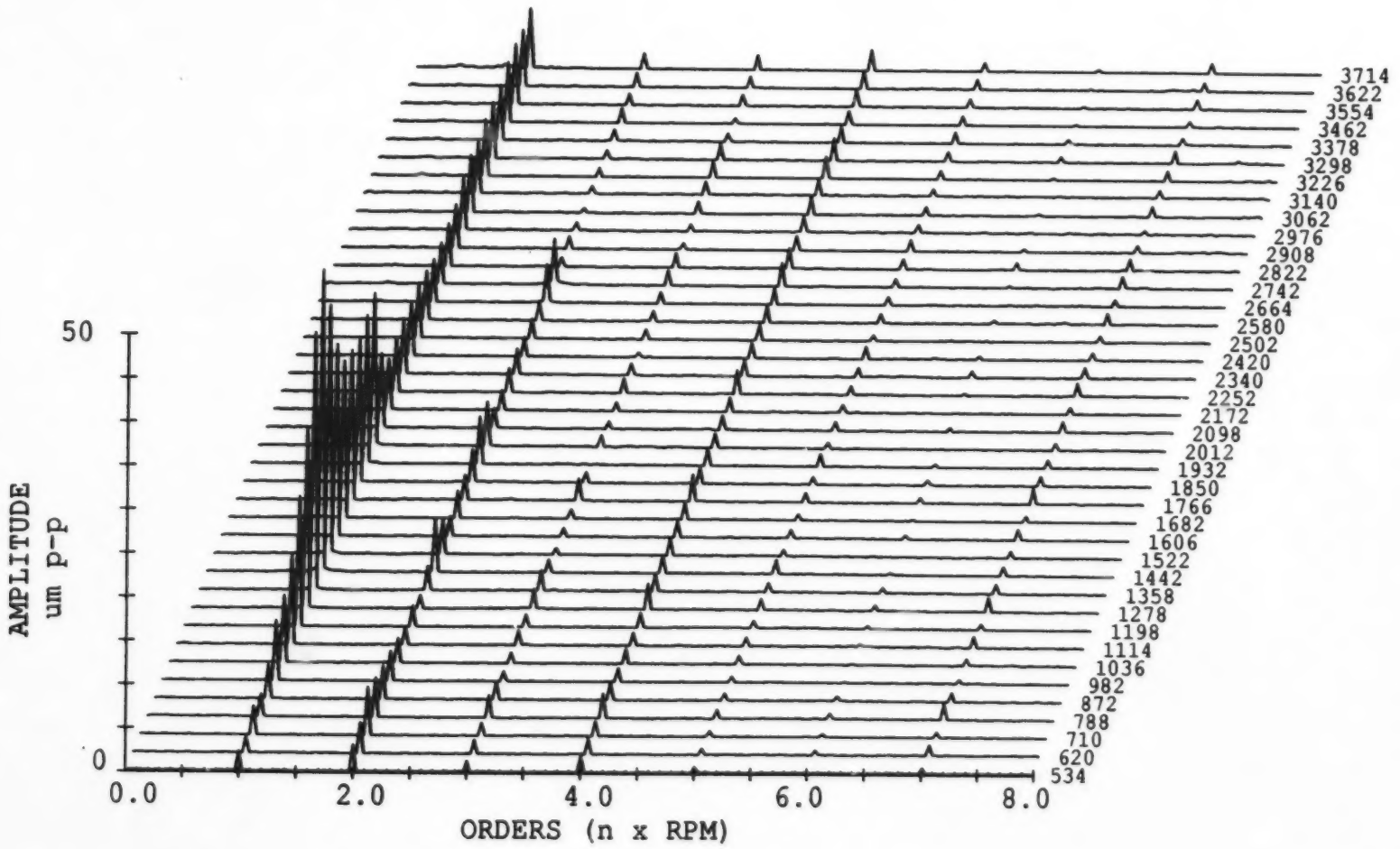

FIGURE 194

89-6

Darlington GS Standby Generator #4
AC Generator

RPM SPECTRAL MAP : Run-down
Date : 10-Mar-1987

Ch # 9 Inboard Brg. Shaft Displacement X-Axis

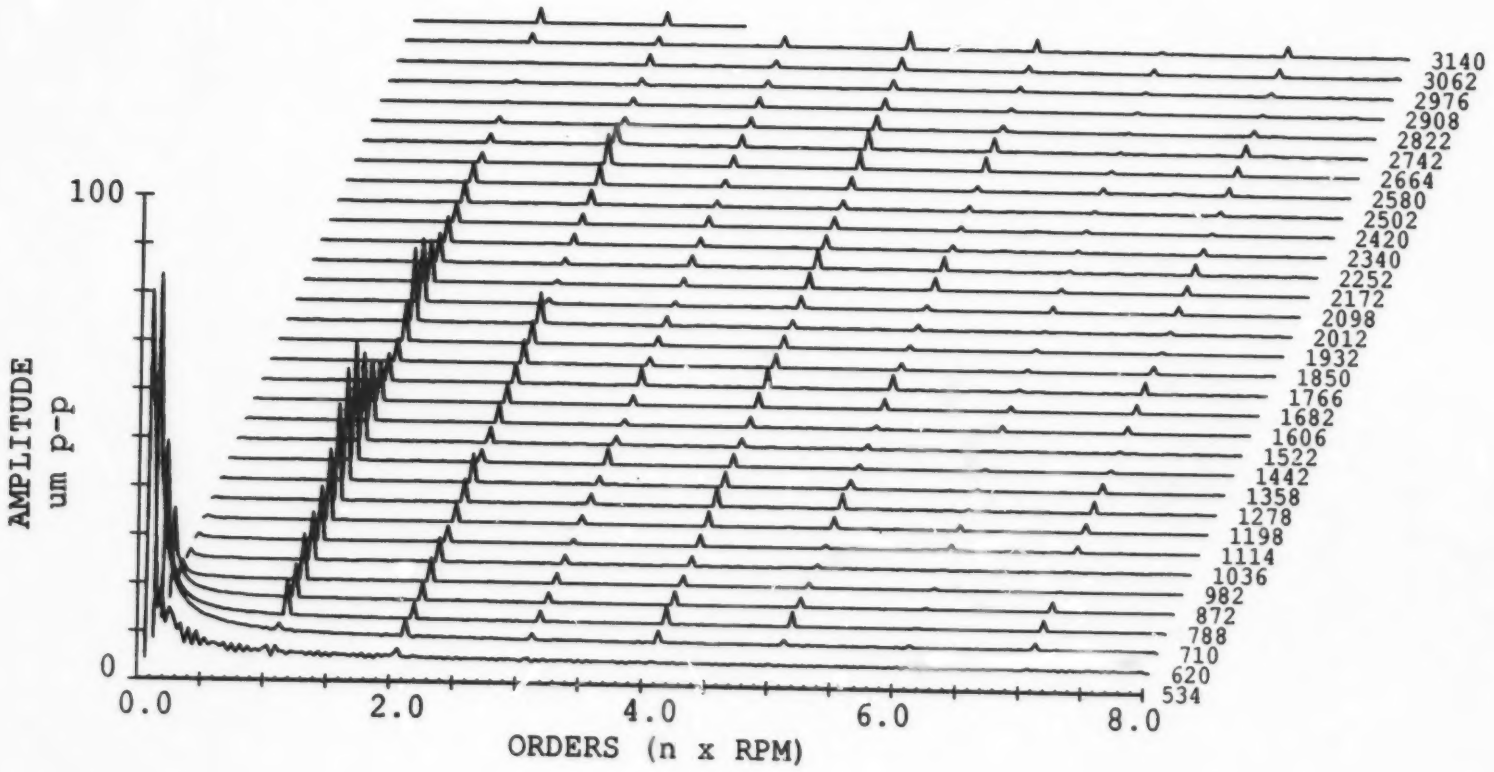

FIGURE 195

89-6

Darlington GS Standby Generator #4
AC Generator

RPM SPECTRAL MAP : Run-down
Date : 10-Mar-1987

Ch # 10 Inboard Brg. Shaft Displacement Y-Axis

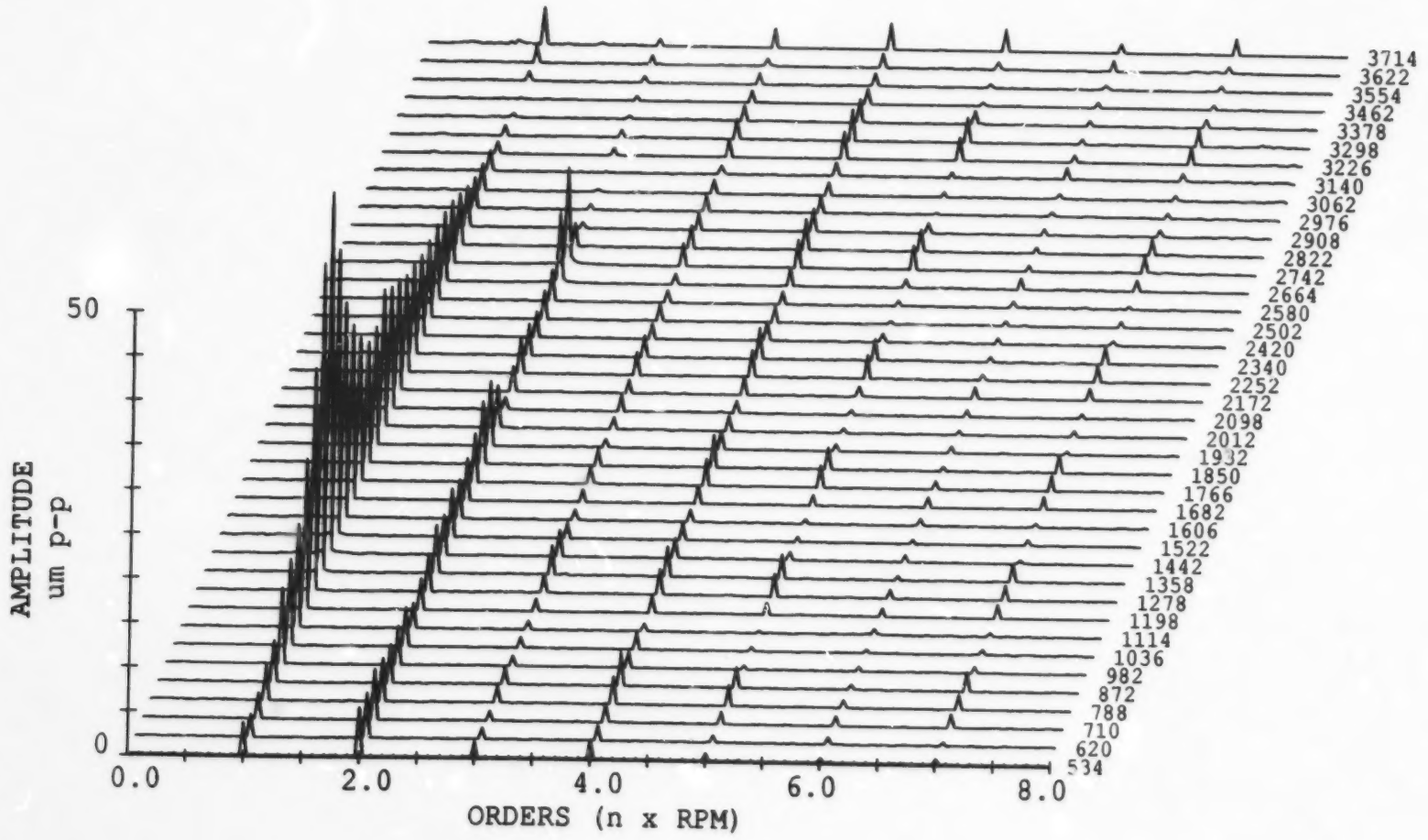

FIGURE 196

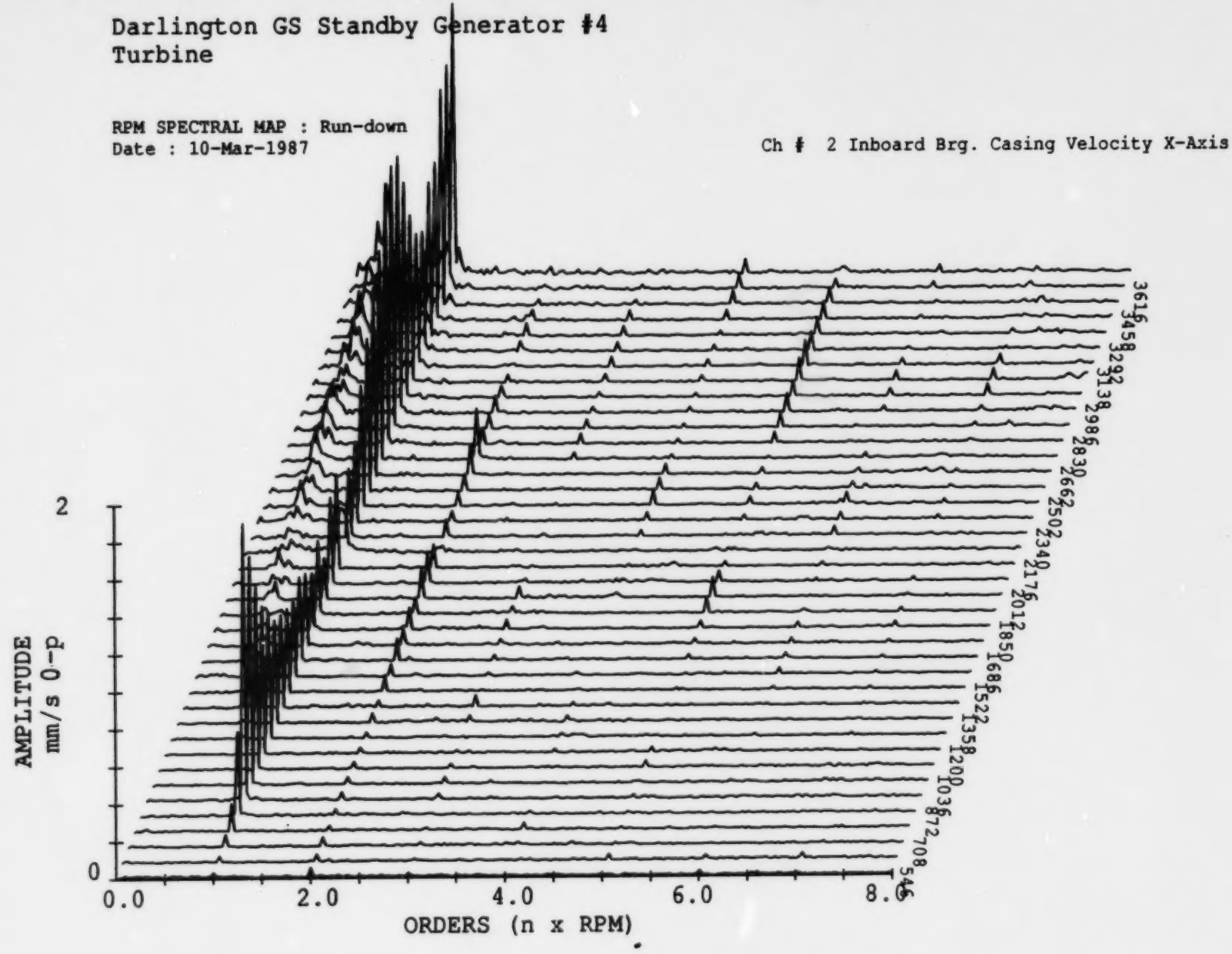
Darlington GS Standby Generator #4
Turbine
RPM SPECTRAL MAP : Run-down
Date : 10-Mar-1987
Ch # 2 Inboard Brg. Casing Velocity X-Axis
AMPLITUDE
mm/s 0-p
2
0
0.0
2.0
4.0
6.0
8.0
ORDERS (n x RPM)
3616
3458
3292
3138
2986
2830
2662
2502
2340
2176
2012
1850
1686
1522
1358
1200
1036
872
708
546

FIGURE 197

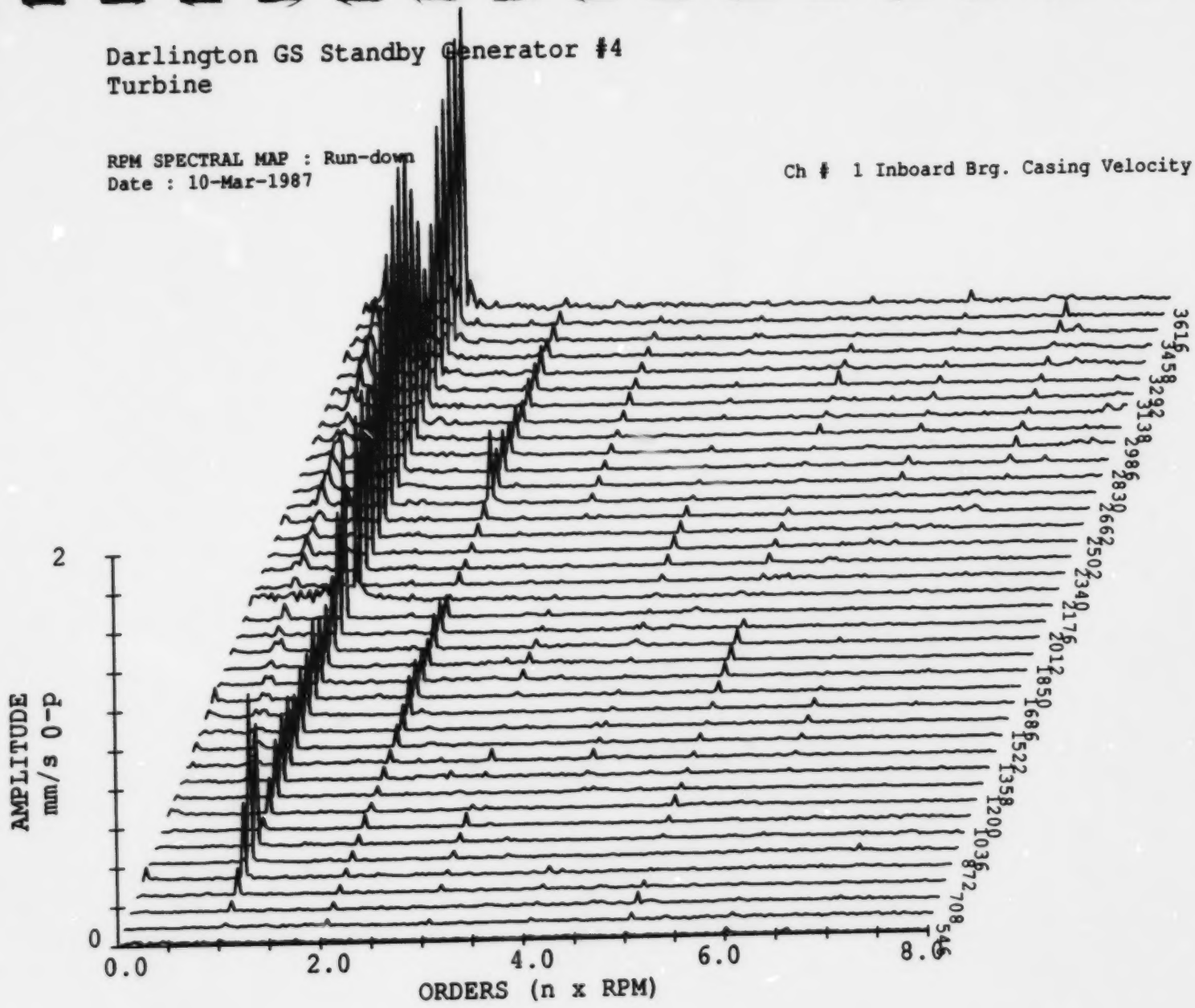

FIGURE 198

89-6

Darlington GS Standby Generator #4
Turbine

RPM SPECTRAL MAP : Run-down
Date : 10-Mar-1987

Ch # 3 Inboard Brg. Casing Velocity Axial

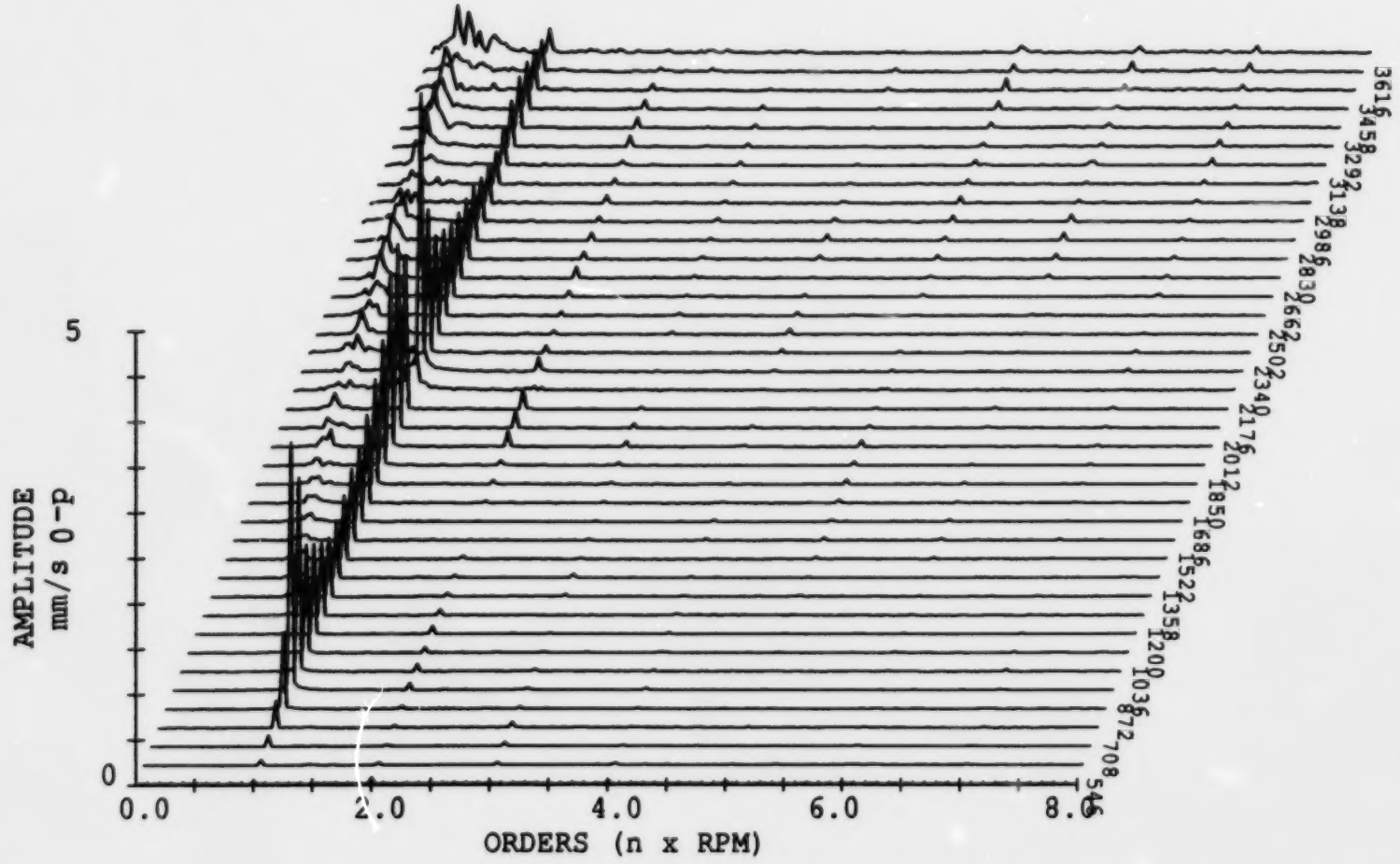

FIGURE 199

89-6

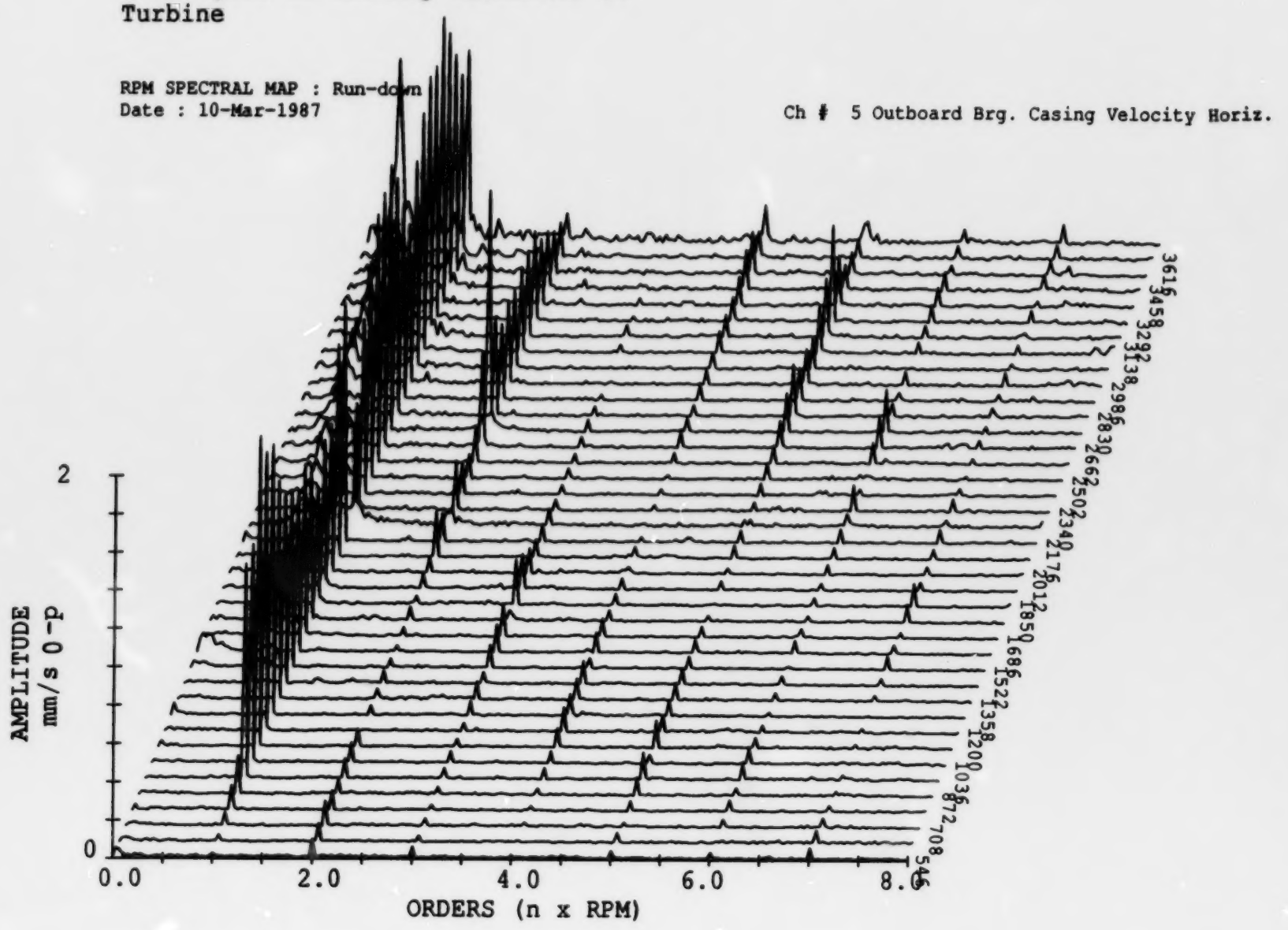

FIGURE 200

89-6

Darlington GS Standby Generator #4
Turbine

RPM SPECTRAL MAP : Run-down
Date : 10-Mar-1987

Ch # 4 Outboard Brg. Casing Velocity Vert.

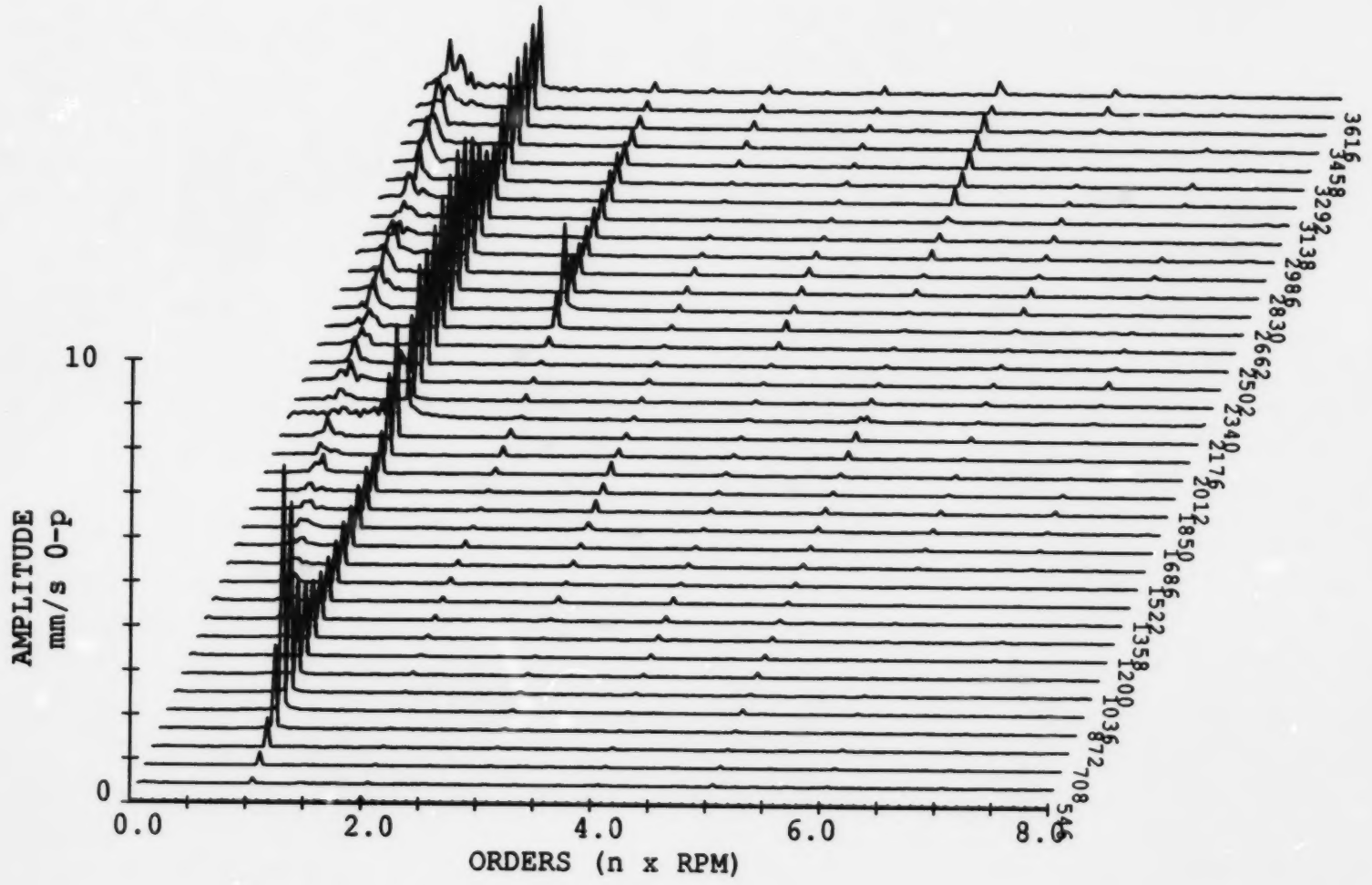

FIGURE 201

89-6

Darlington GS Standby Generator #4
Turbine

RPM SPECTRAL MAP : Run-down
Date : 10-Mar-1987

Ch # 6 Outboard Brg. Casing Velocity Axial

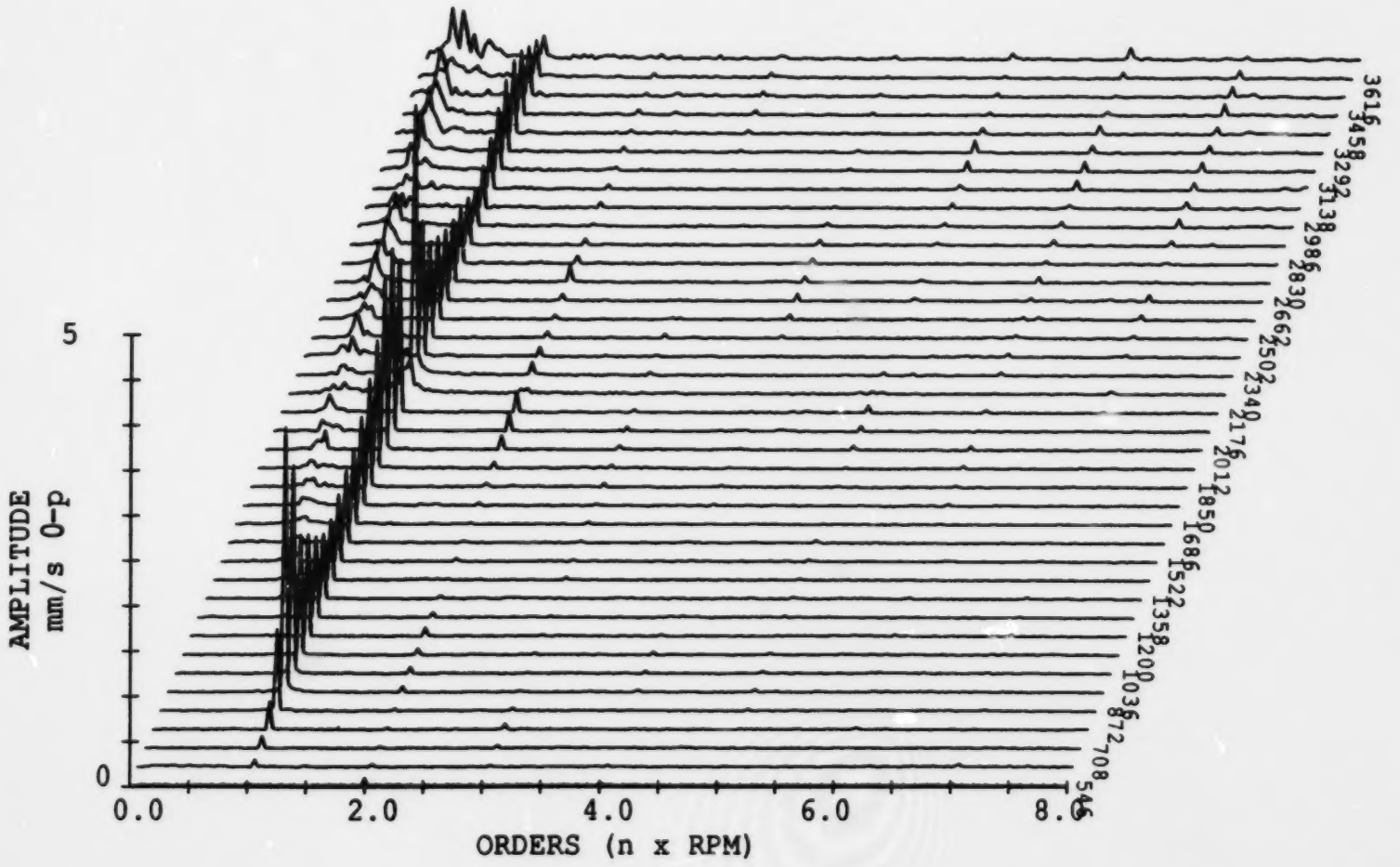

FIGURE 202

89-6

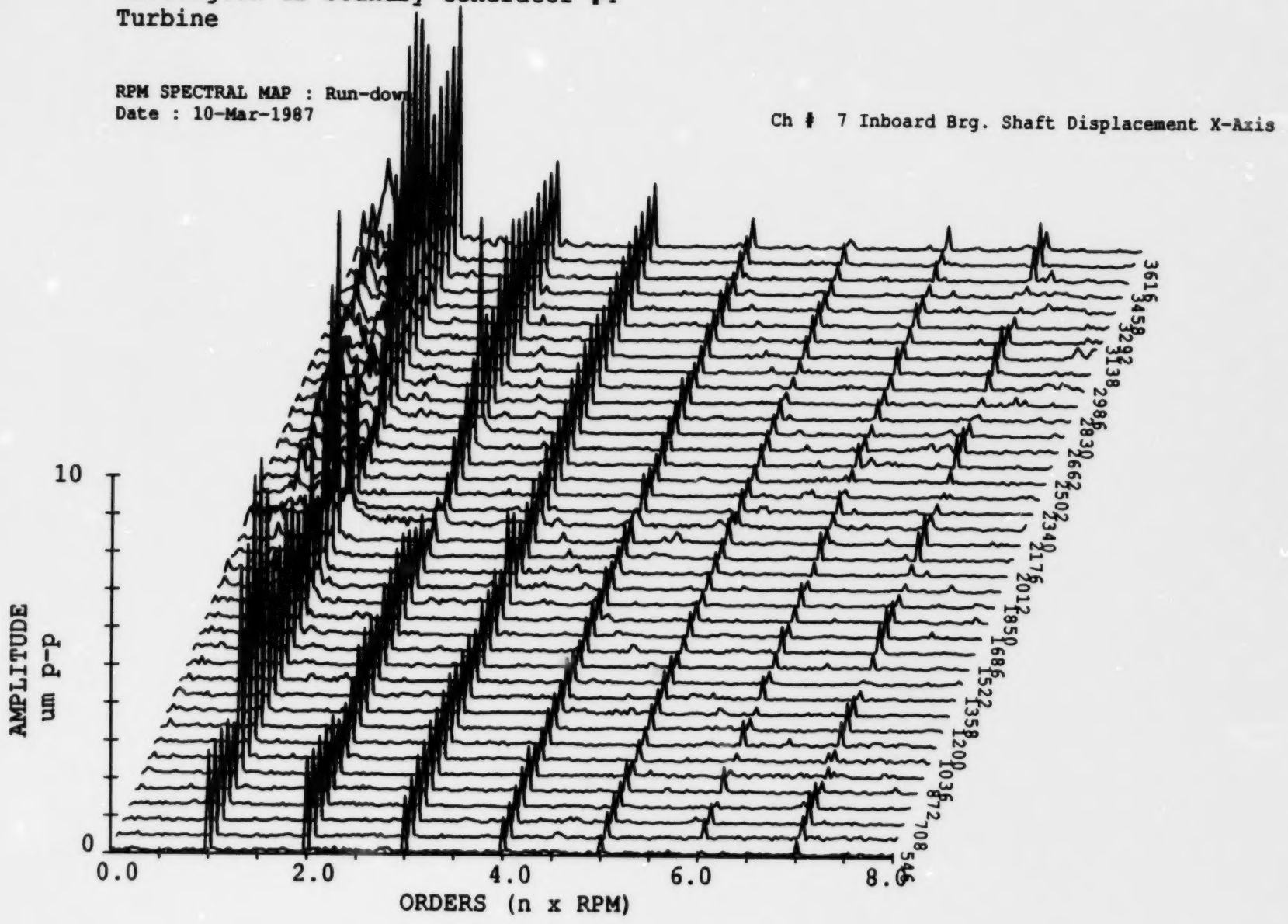

FIGURE 203

89-6

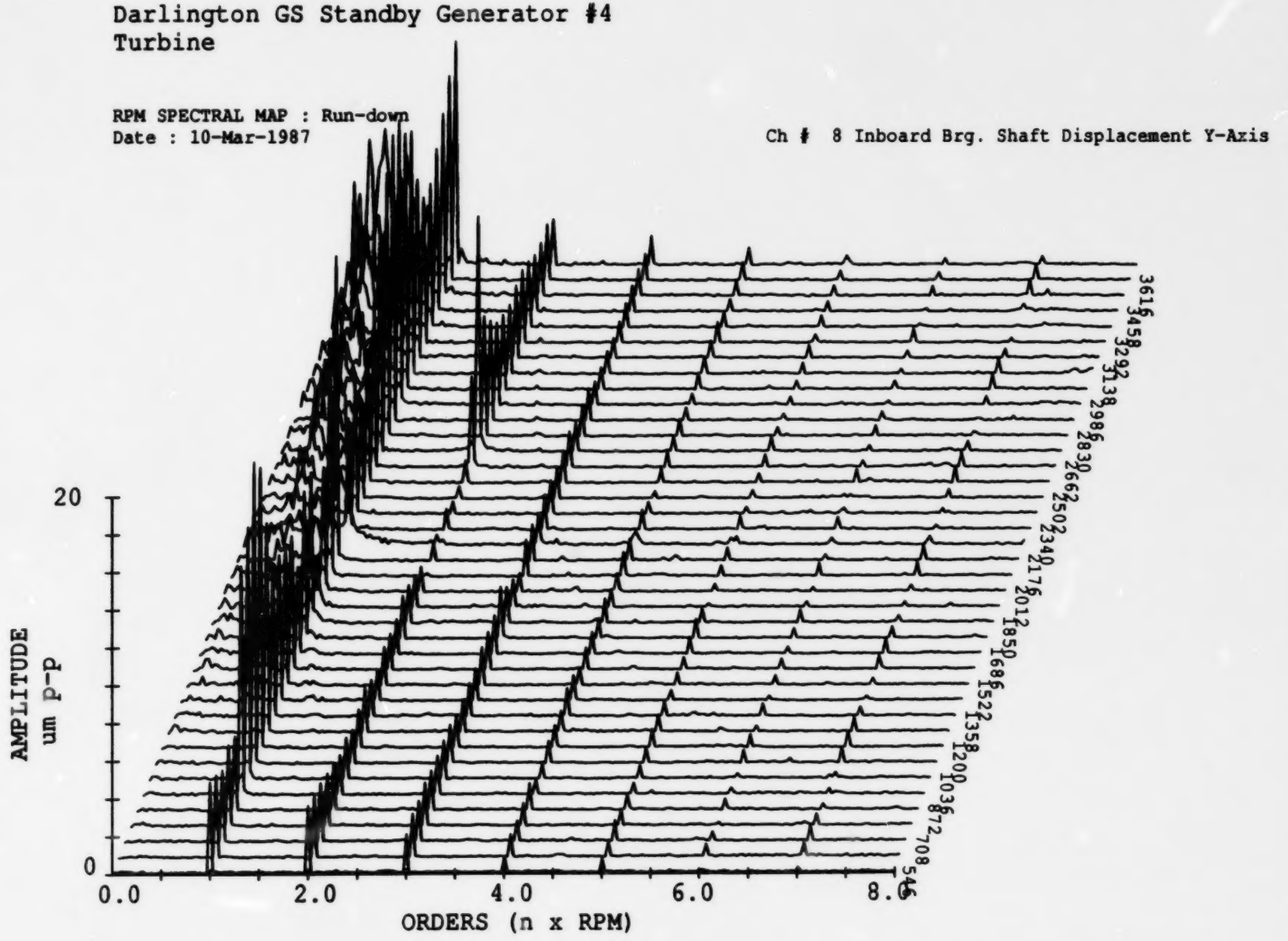

FIGURE 204

89-6

Darlington GS Standby Generator #4
Turbine

RPM SPECTRAL MAP : Run-down
Date : 10-Mar-1987

Ch # 9 Outboard Brg. Shaft Displacement X-Axis

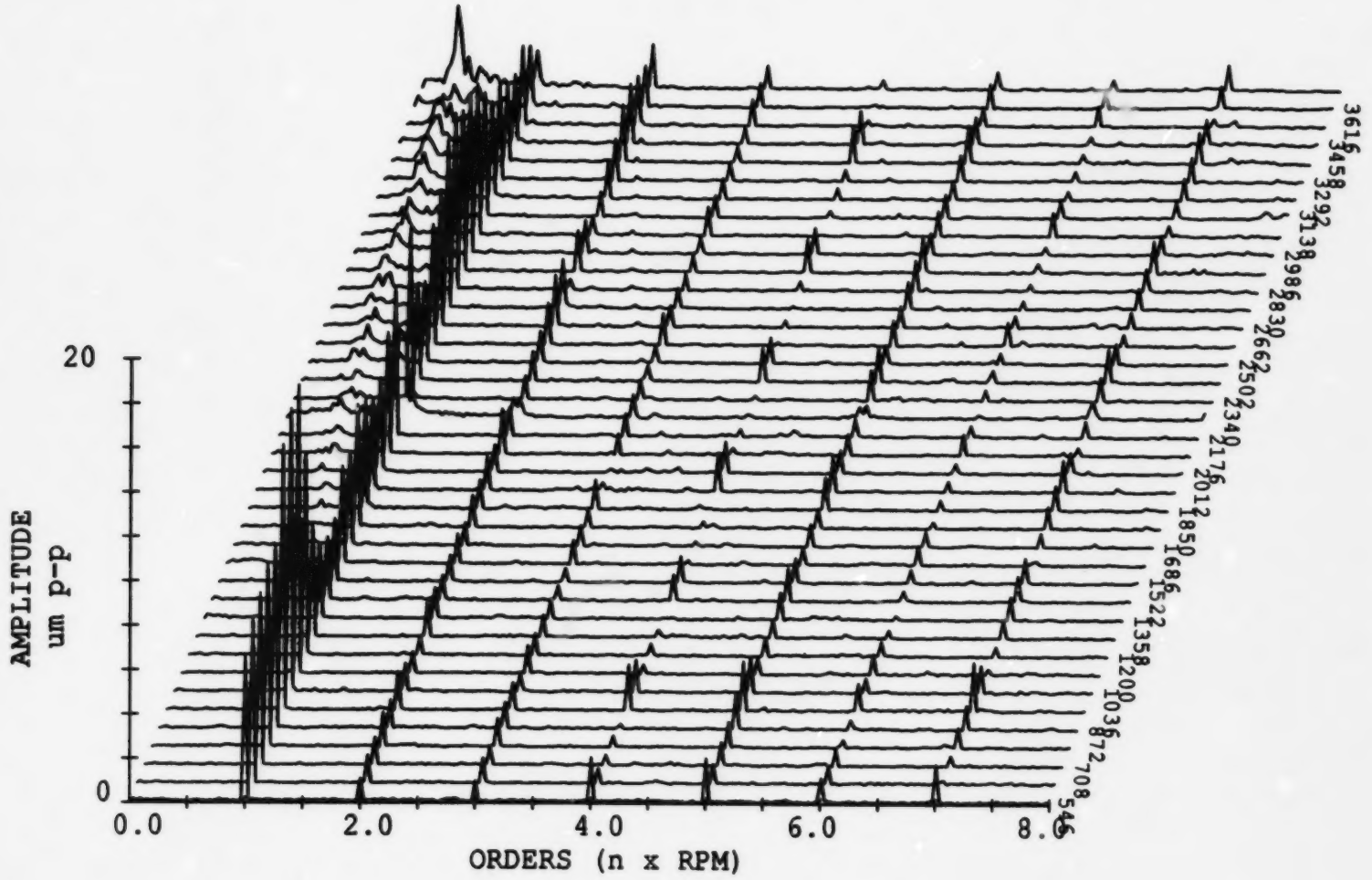

FIGURE 205

89-6

Darlington GS Standby Generator #4
Turbine

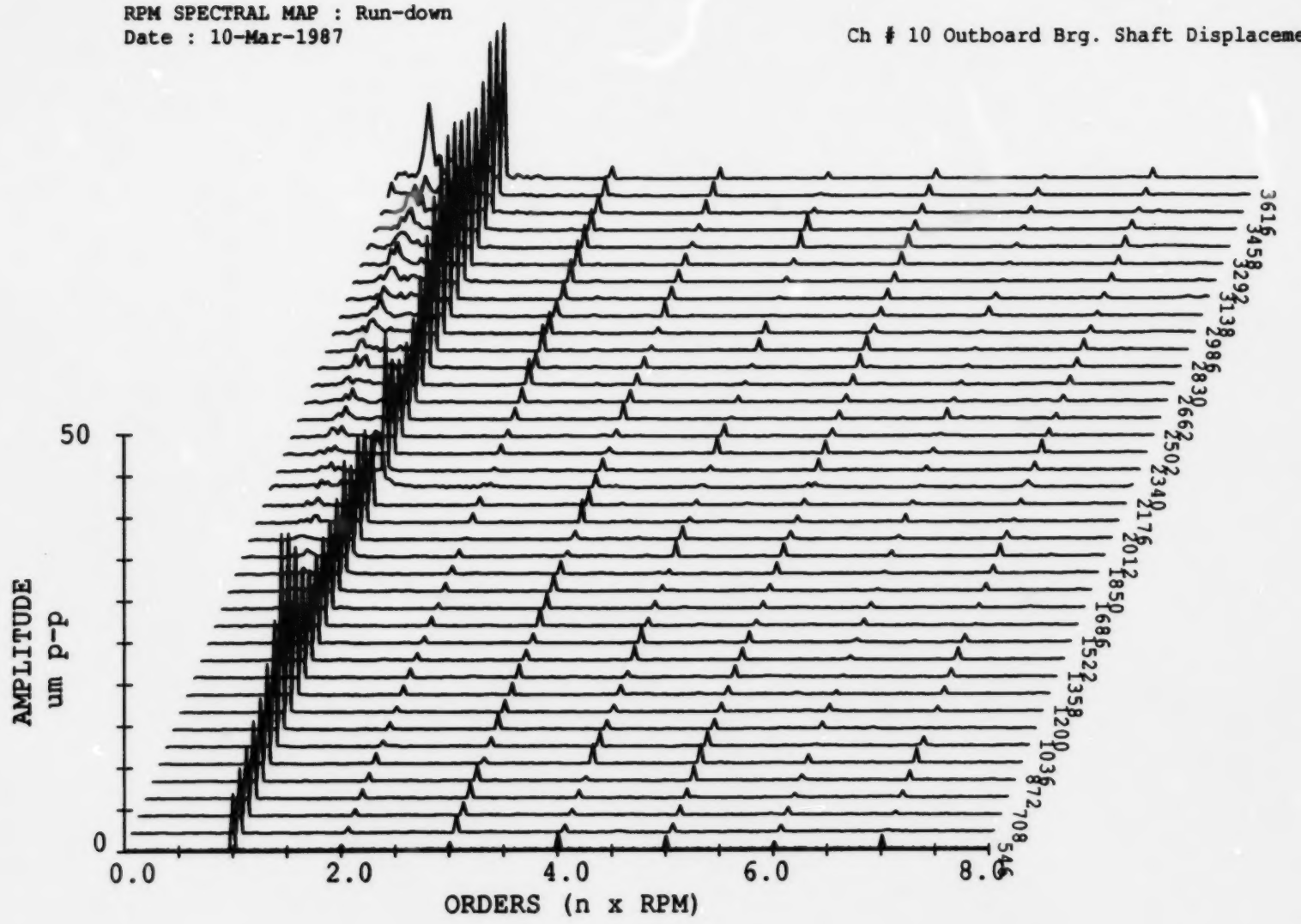

FIGURE 206

89-6

DARLINGTON GS 'A' STANDBY GENERATOR #4 - AC GENERATOR OUTBOARD BEARING CASING COMPLIANCE TRANSFER FUNCTION (HORIZONTAL DIRECTION)

DNGS SG#4 GEN OB HORIZ IMPACT
100kHz A: AC/ 50V B: AC/ 50V INST 0/16 DUAL 1k

	XFER FUNC	MAG - PH	
1	30.00Hz	.194E-8 EU/EU	160.8 deg
2	60.00	.156E-8	179.1
3	81.25	.119E-7	104.2
4	176.25	.289E-8	96.7
5	215.00	.965E-9	62.1
6	350.00	.143E-8	96.3
7			
8			
9			
10			

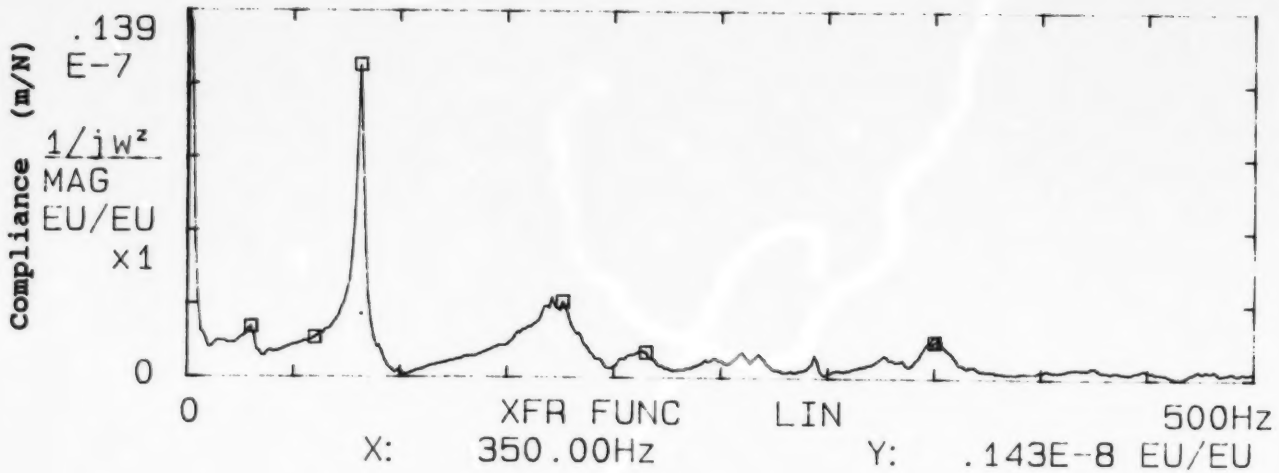

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FIGURE 207

89-6

DARLINGTON GS 'A' STANDBY GENERATOR #4 - AC GENERATOR OUTBOARD BEARING CASING COMPLIANCE TRANSFER FUNCTION (VERTICAL DIRECTION)

DNGS SG#4 GEN OB VERT IMPACT
500Hz A: AC/ 50V B: AC/ 50V INST 0/16 DUAL 1k

	XFER FUNC	MAG - PH	
1	25.00Hz	.635E-10EU/EU	-63.3 deg
2	35.00	.969E-10	-119.0
3	60.00	.363E-10	-52.4
4	82.50	.524E-10	34.8
5	108.75	.720E-10	-85.2
6	211.25	.762E-10	-62.2
7	271.25	.897E-10	-72.2
8	321.25	.858E-10	-123.8
9			
10			

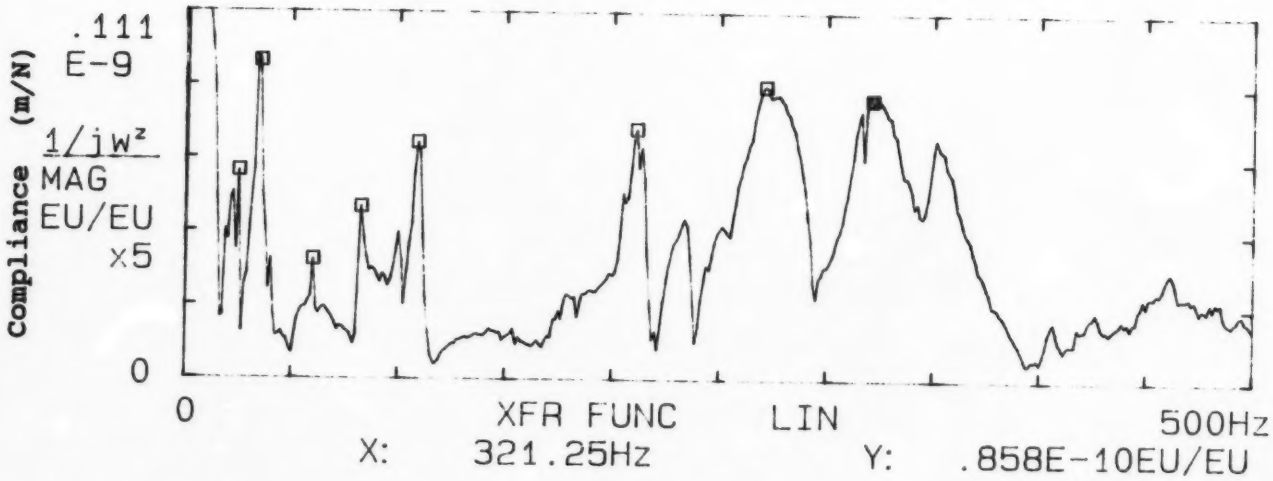

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FIGURE 208

89-6

DARLINGTON GS 'A' STANDBY GENERATOR #4 - AC GENERATOR OUTBOARD BEARING CASING COMPLIANCE TRANSFER FUNCTION (AXIAL DIRECTION)

DNGS SG#4 GEN OB AXIAL — IMPACT

500Hz A: AC/ 50V B: AC/ 50V INST 0/16 DUAL 1k

	XFER FUNC	MAG - PH	
1	33.75Hz	.142E-7 EU/EU	-65.9 deg
2	60.00	.263E-9	-176.3
3	78.75	.119E-9	-25.9
4	95.00	.156E-8	-94.2
5	213.75	.992E-8	-136.3
6	293.75	.445E-8	116.4
7			
8			
9			
10			

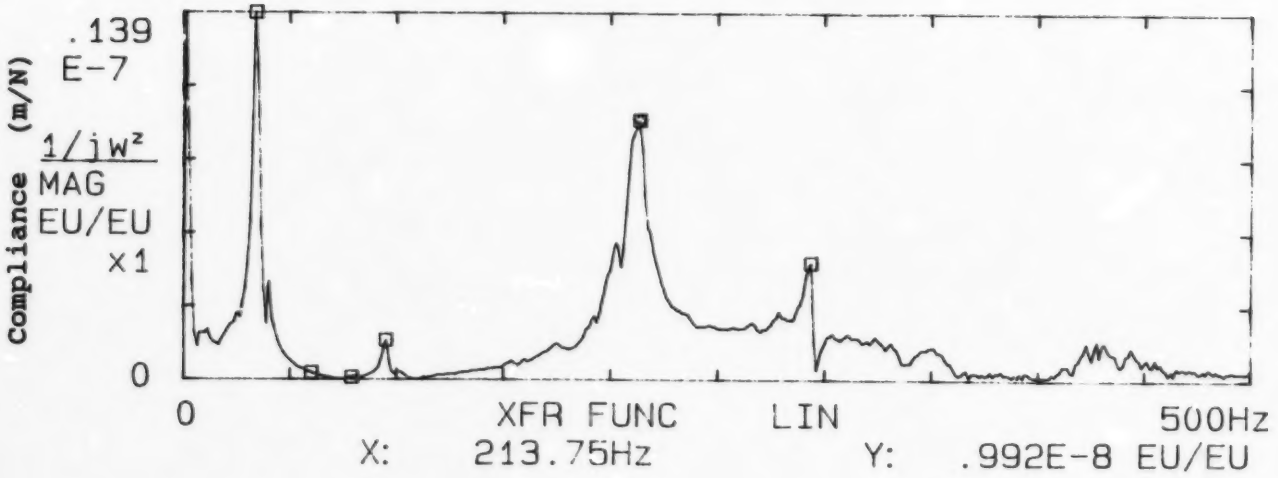

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FIGURE 209
89-6

DARLINGTON G8 'A' STANDBY GENERATOR #4 - AC GENERATOR INBOARD BEARING CASING COMPLIANCE TRANSFER FUNCTION (HORIZONTAL DIRECTION)

DNGS SG#4 GEN IB HORIZ IMPACT
500Hz A: AC/ 50V B: AC/ 50V INST 0/16 DUAL 1k

	XFER FUNC	MAG -- PH	
1	30.50Hz	.151E-8 EU/EU	155.2 deg
2	60.00	.116E-8	-179.9
3	81.00	.377E-8	138.2
4	89.50	.510E-8	89.8
5	120.00	.678E-9	165.5
6	133.50	.111E-8	115.5
7	185.50	.171E-8	111.5
8			
9			
10			

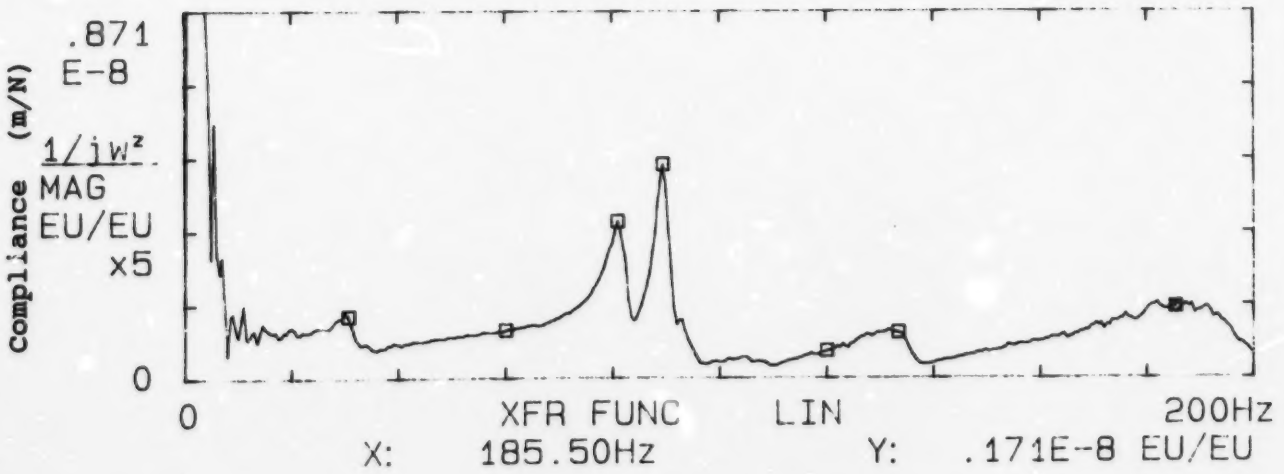

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FIGURE 210
89-6

DARLINGTON GS 'A' STANDBY GENERATOR #4 - AC GENERATOR INBOARD BEARING CASING COMPLIANCE TRANSFER FUNCTION (VERTICAL DIRECTION)

DNGS SG#4 GEN IB VERT IMPACT
500Hz A: AC/ 50V B: AC/ 50V INST 0/16 DUAL 1k

	XFER FUNC	MAG - PH	
1	60.00Hz	.247E-9 EU/EU	-367.7 deg
2	100.00	.453E-9	-389.0
3	107.50	.404E-9	-385.5
4	120.00	.267E-9	-374.3
5	142.50	.376E-9	-389.9
6	175.00	.444E-9	-425.1
7	207.50	.245E-9	-395.4
8	270.00	.499E-9	-431.9
9	318.75	.338E-9	-443.9
10	351.25	.546E-9	-457.8

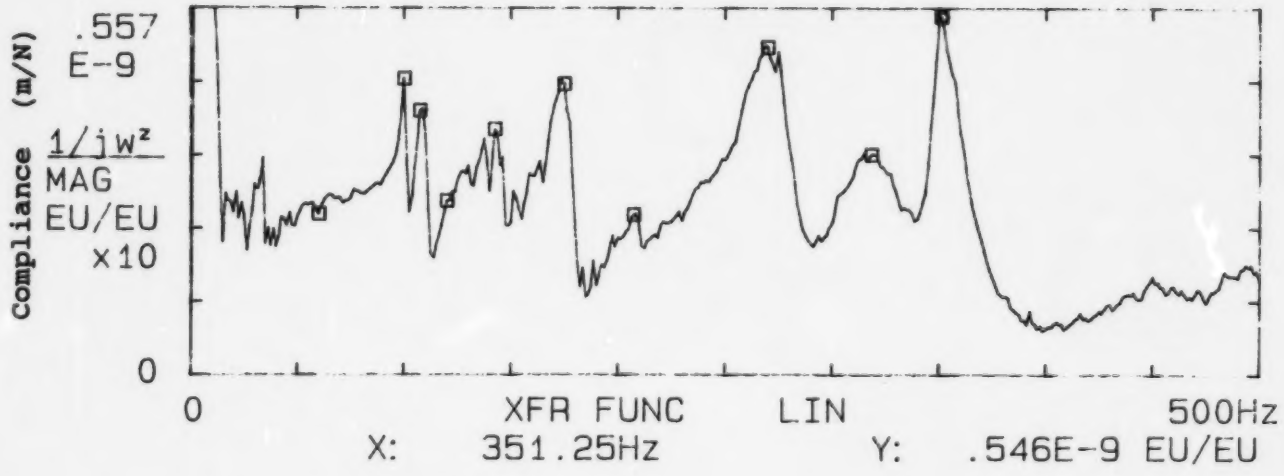

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FIGURE 211
89-6

DARLINGTON GS 'A' STANDBY GENERATOR #4 - AC GENERATOR INBOARD BEARING CASING COMPLIANCE TRANSFER FUNCTION (AXIAL DIRECTION)

DNGS SG#4 GEN IB AXIAL IMPACT
500Hz A: AC/ 50V B: AC/ 50V INST 0/16 DUAL 1k

	XFER FUNC MAG - PH		
1	34.50Hz	.652E-8 EU/EU	-97.3 deg
2	39.50	.227E-8	-136.4
3	60.00	.186E-9	-172.2
4	95.00	.821E-9	-93.1
5	102.00	.594E-9	-135.8
6	120.00	.442E-10	-98.8
7	178.50	.143E-8	-134.6
8			
9			
10			

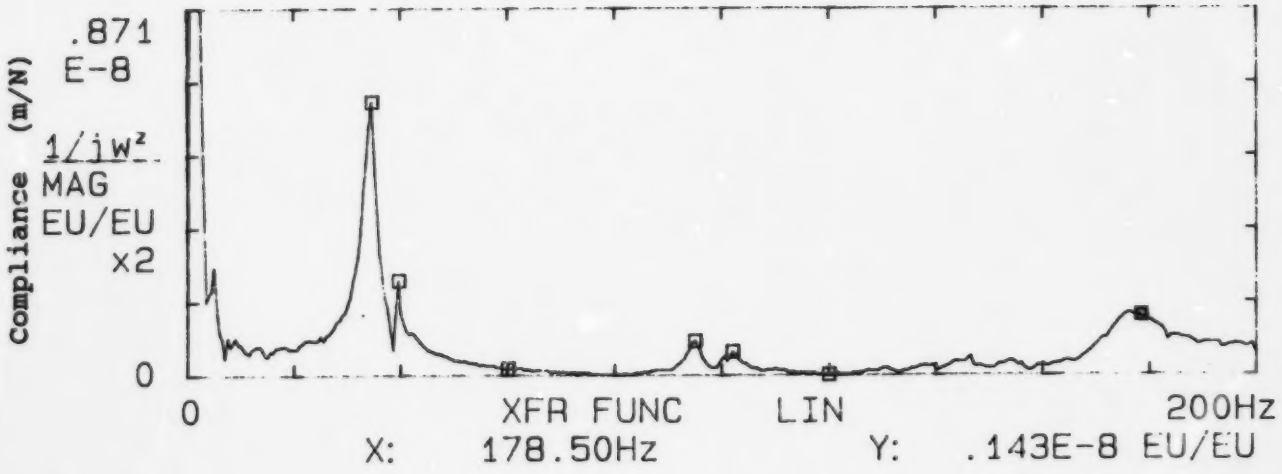

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FIGURE 212
89-6

DARLINGTON GS 'A' STANDBY GENERATOR #4 - AC GENERATOR FRAME COMPLIANCE TRANSFER FUNCTION (HORIZONTAL DIRECTION)

DNGS SG#4 GEN FRAME WEST LOC 11 IMPACT
500Hz A: AC/ 50V B: AC/ 50V INST 0/16 DUAL 1k

	XFER FUNC	MAG	PH
1	34.00Hz	.833E-9 EU/EU	-37.1 deg
2	37.00	.119E-8	-71.5
3	40.50	.535E-9	-93.4
4	45.50	.154E-8	-75.8
5	60.00	.295E-9	-7.9
6	65.50	.825E-9	-69.6
7	82.50	.405E-9	-37.5
8			
9			
10			

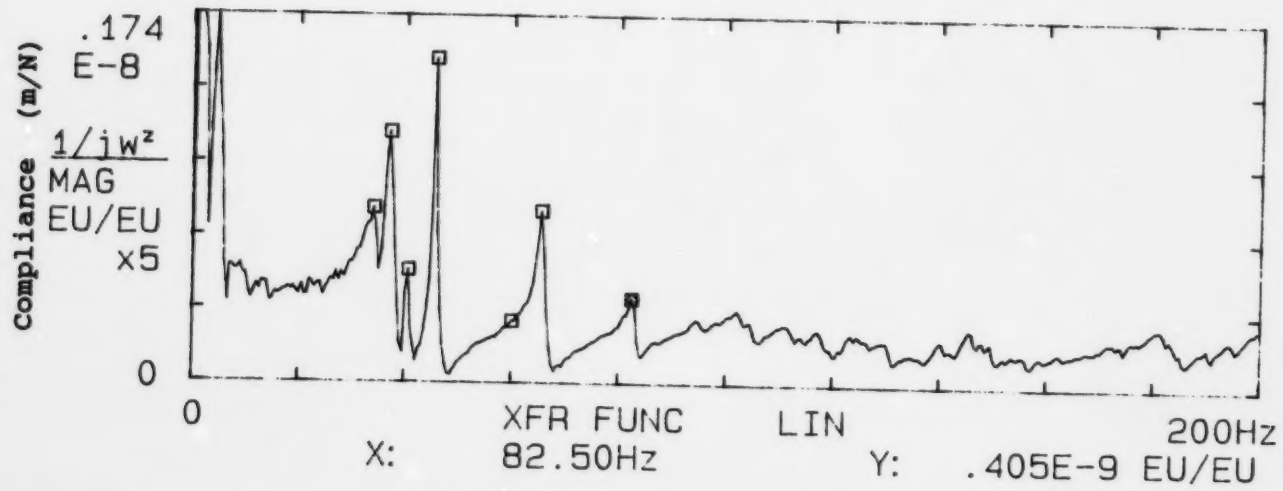

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FIGURE 213

DARLINGTON GS 'A' STANDBY GENERATOR #4 - POWER TURBINE INBOARD BEARING PEDESTAL COMPLIANCE TRANSFER FUNCTION (HORIZONTAL DIRECTION)

DNGS SG#4 PWR TURB IB HORIZ
500Hz A: AC/ 50V B: AC/ 50V INST IMPACT 0/16 DUAL 1k

	XFER FUNC MAG	- PH	
1	21.50Hz	.604E-8 EU/EU	-44.8 deg
2	23.50	.687E-8	-104.8
3	49.50	.702E-8	-89.2
4	60.00	.447E-9	-127.6
5	62.50	.121E-8	-131.3
6	79.00	.420E-9	-48.0
7	103.50	.765E-9	-56.9
8	120.00	.302E-9	-15.4
9			
10			

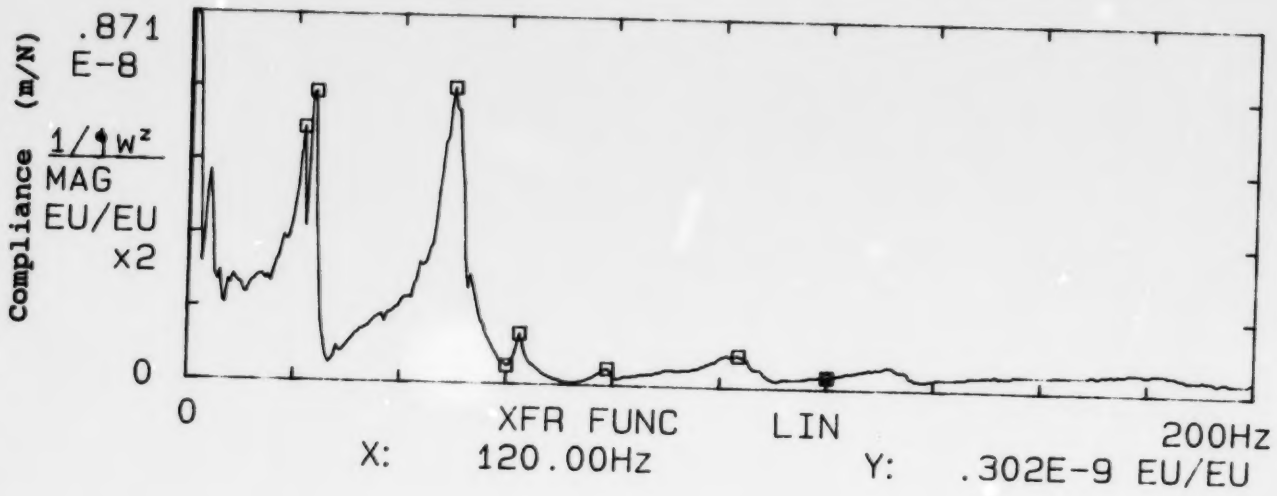

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FIGURE 214
89-6

DARLINGTON GS 'A' STANDBY GENERATOR #4 - POWER TURBINE INBOARD BEARING PEDESTAL COMPLIANCE TRANSFER FUNCTION (VERTICAL DIRECTION)

DNGS SG#4 PWR TURB IB VERT
500Hz A: AC/ 50V B: AC/ 50V INST IMPACT 0/16 DUAL 1k

	XFER FUNC	MAG	PH
1	16.50Hz	.128E-7 EU/EU	-73.9 deg
2	49.50	.179E-8	-22.3
3	60.00	.652E-8	-52.8
4	61.00	.757E-8	-90.2
5	74.00	.427E-9	-135.2
6	92.00	.102E-8	-72.1
7	105.00	.142E-8	-101.0
8	120.00	.182E-9	-137.9
9	133.00	.356E-9	-103.0
10			

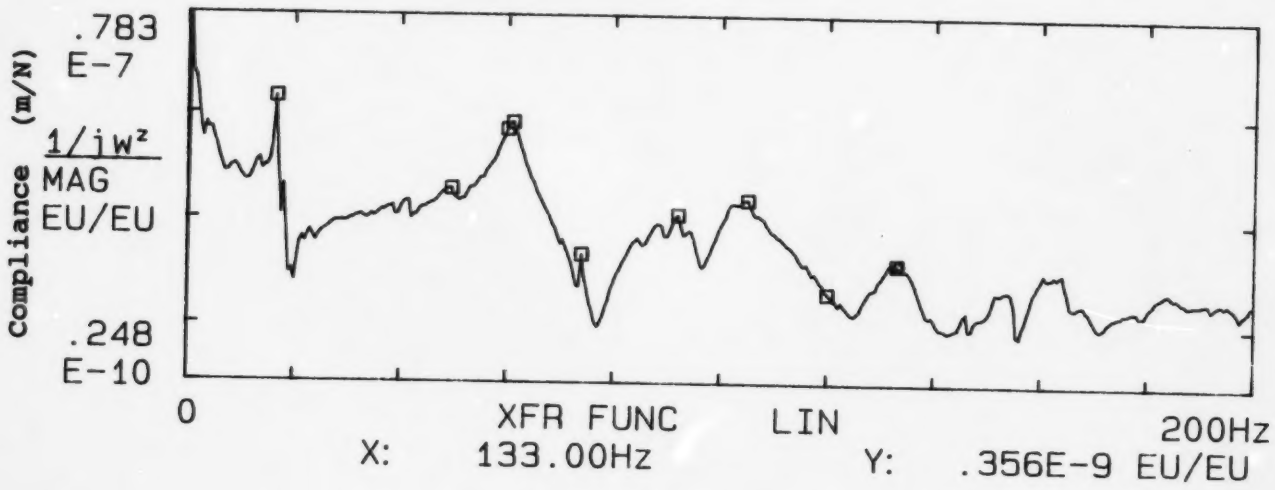

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FIGURE 215
89-6

DARLINGTON GS 'A' STANDBY GENERATOR #4 - POWER TURBINE INBOARD BEARING PEDESTAL COMPLIANCE TRANSFER FUNCTION (AXIAL DIRECTION)

DNGS SG#4 PWR TURB IB AXIAL — IMPACT
500Hz A: AC/ 50V B: AC/ 50V INST 0/16 DUAL 1k

	XFER FUNC	MAG - PH	
1	16.50Hz	.326E-7 EU/EU	85.6 deg
2	18.00	.111E-7	20.9
3	24.00	.178E-8	49.5
4	39.00	.588E-8	107.3
5	41.50	.166E-7	113.2
6	62.00	.587E-9	19.6
7	79.00	.136E-8	93.9
8	92.00	.881E-10	130.3
9	130.00	.127E-8	89.0
10			

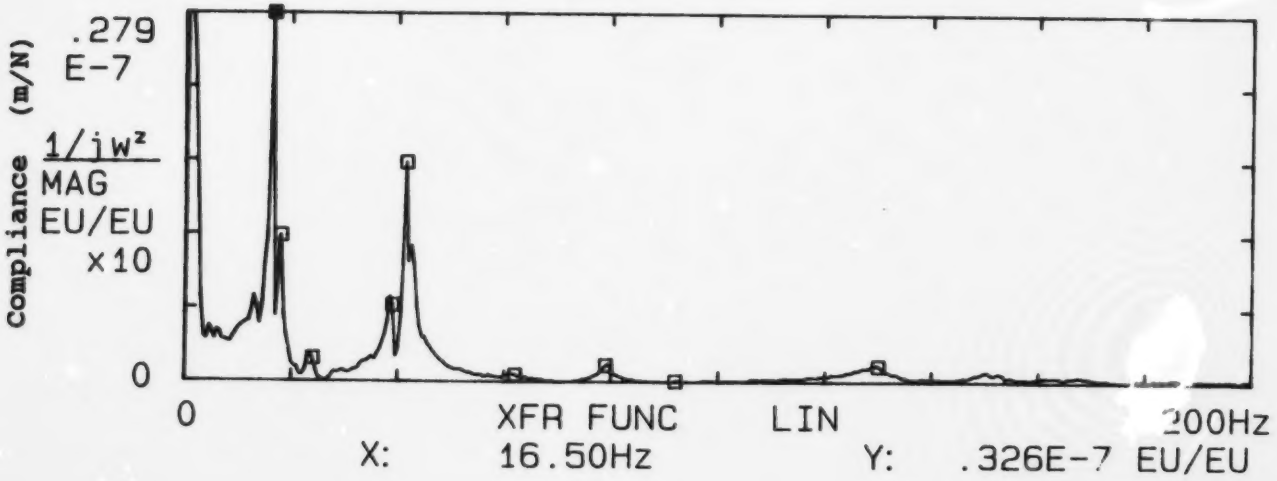

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FIGURE 216
89-6

DARLINGTON GS 'A' STANDBY GENERATOR #4 - POWER TURBINE OUTBOARD BEARING PEDESTAL COMPLIANCE TRANSFER FUNCTION (HORIZONTAL DIRECTION)

DNGS SG#4 PWR TURB OB HORIZ IMPACT
500Hz A: AC/ 50V B: AC/ 50V INST 0/16 DUAL 1k

	XFER FUNC	MAG - PH	
1	21.50Hz	.108E-8 EU/EU	127.4 deg
2	23.50	.159E-8	68.5
3	59.50	.321E-10	13.1
4	79.50	.110E-9	-94.0
5	104.00	.275E-10	-83.0
6			
7			
8			
9			
10			

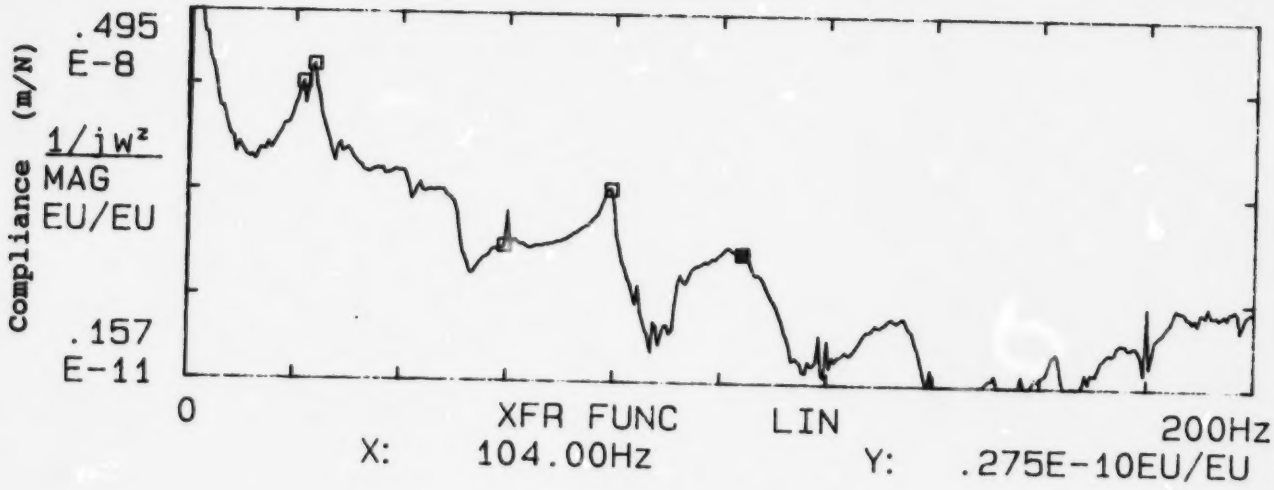

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FIGURE 217
89-6

DARLINGTON GS 'A' STANDBY GENERATOR #4 - POWER TURBINE OUTBOARD BEARING PEDESTAL COMPLIANCE TRANSFER FUNCTION (VERTICAL DIRECTION)

DNGS SG#4 PWR TURB OB VERT IMPACT
500Hz A: AC/ 50V B: AC/ 50V INST 0/16 DUAL 1k

	XFER FUNC	MAG - PH	
1	16.50Hz	.414E-8 EU/EU	640.5 deg
2	39.00	.176E-9	608.0
3	41.50	.208E-9	642.6
4	61.50	.194E-9	591.9
5	84.50	.194E-9	462.8
6	88.50	.117E-9	440.5
7			
8			
9			
10			

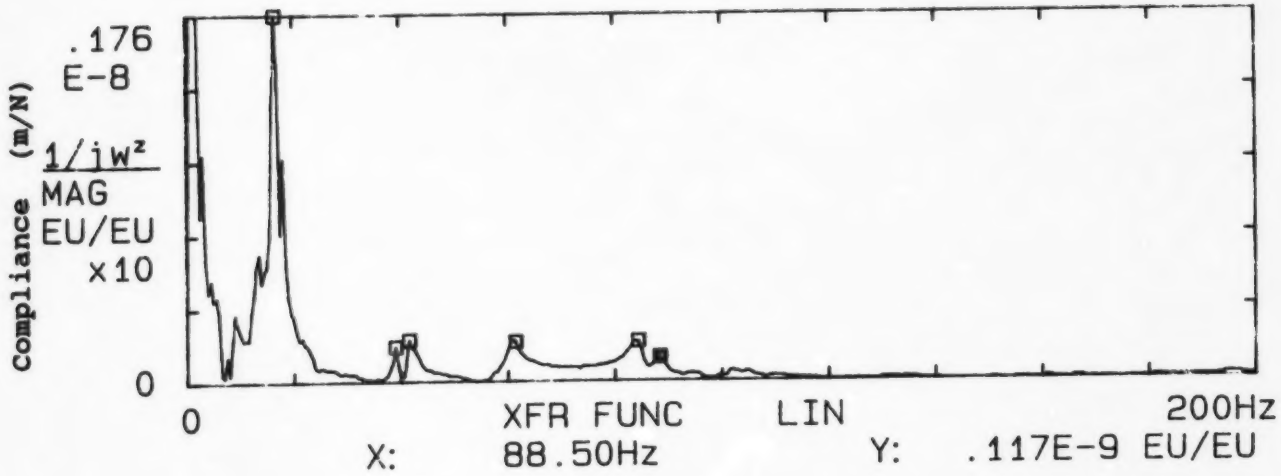

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FIGURE 218
89-6

DARLINGTON GS 'A' STANDBY GENERATOR #4 - POWER TURBINE OUTBOARD BEARING PEDESTAL COMPLIANCE TRANSFER FUNCTION (AXIAL DIRECTION)

DNGS SG#4 PWR TURB OB AXIAL IMPACT
500Hz A: AC/ 50V B: AC/ 50V INST 0/16 DUAL 1k

	XFER FUNC MAG - PH		
1	16.50Hz	.357E-8 EU/EU	81.9 deg
2	18.00	.128E-8	19.1
3	39.00	.505E-9	102.7
4	41.50	.147E-8	115.0
5	60.00	.779E-10	11.0
6	79.00	.776E-10	-65.0
7	120.00	.649E-11	136.1
8	130.50	.564E-10	46.6
9			
10			

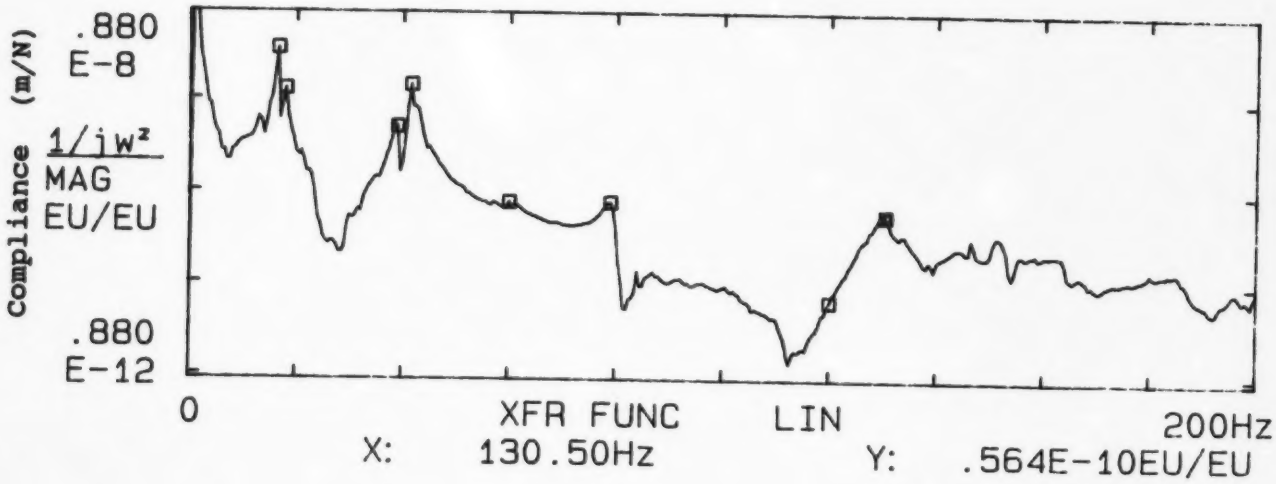

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FIGURE 219
89-6

DARLINGTON GS 'A' STANDBY GENERATOR #4 - POWER TURBINE SKID INBOARD END COMPLIANCE TRANSFER FUNCTION (HORIZONTAL DIRECTION)

DNGS SG#4 SKID GEN END WEST HORIZ LOC 24 IMPACT
500Hz A: AC/ 50V B: AC/ 50V INST 0/16 DUAL 1k

	XFER FUNC	MAG - PH	
1	49.50Hz	.352E-8 EU/EU	-83.9 deg
2	60.00	.261E-9	-368.5
3	62.50	.621E-9	-470.4
4	79.00	.121E-8	-791.9
5	92.00	.169E-8	-808.4
6	105.00	.683E-9	-831.2
7	120.00	.680E-10	-901.3
8			
9			
10			

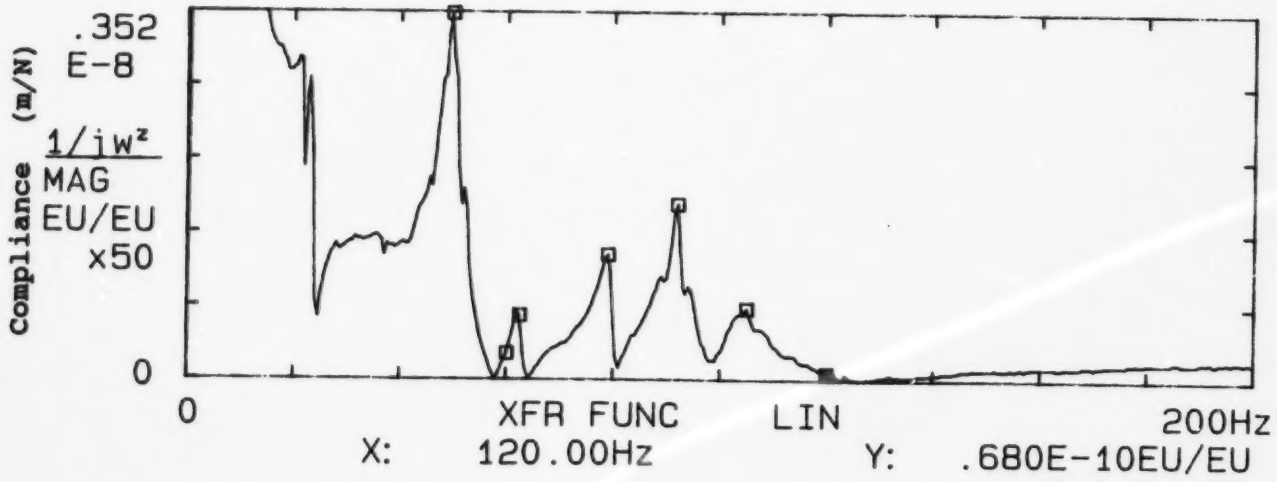

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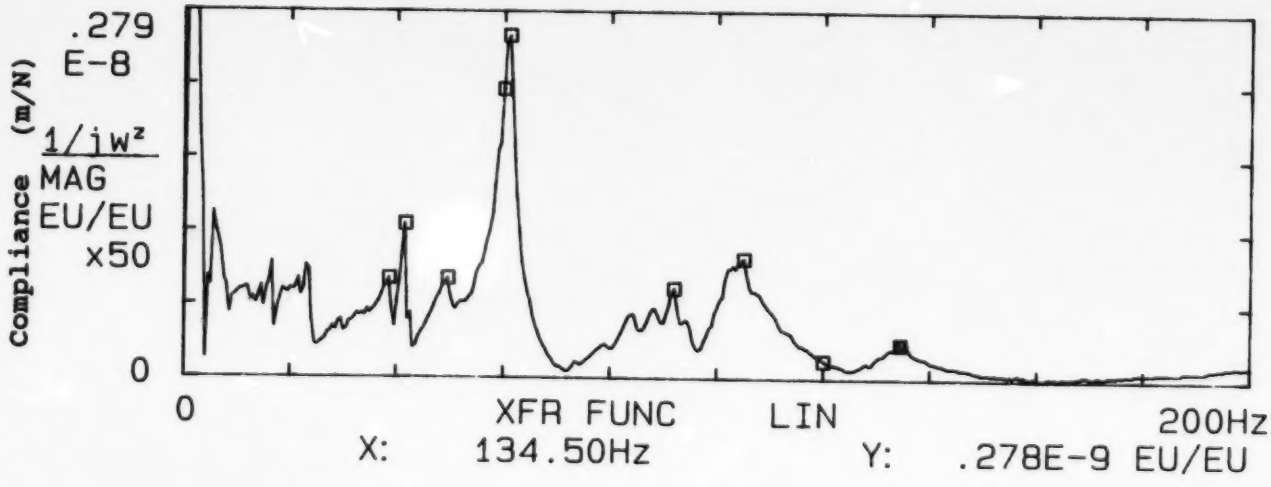
FIGURE 220
89-6

DARLINGTON GS 'A' STANDBY GENERATOR #4 - POWER TURBINE SKID INBOARD END COMPLIANCE TRANSFER FUNCTION (VERTICAL DIRECTION)

DNGS SG#4 SKID GEN END WEST VERT LOC 27 IMPACT
500Hz A: AC/ 50V B: AC/ 50V INST 0/16 DUAL 1k

	XFER FUNC MAG - PH		
1	38.50Hz	.765E-9 EU/EU	156.2 deg
2	41.50	.117E-8	128.7
3	49.50	.768E-9	150.2
4	60.00	.220E-8	125.7
5	61.00	.261E-8	87.8
6	92.00	.694E-9	105.1
7	105.00	.923E-9	73.8
8	120.00	.145E-9	23.0
9	134.50	.278E-9	56.6
10			



24/05/88 21:58

FIGURE 221
89-6

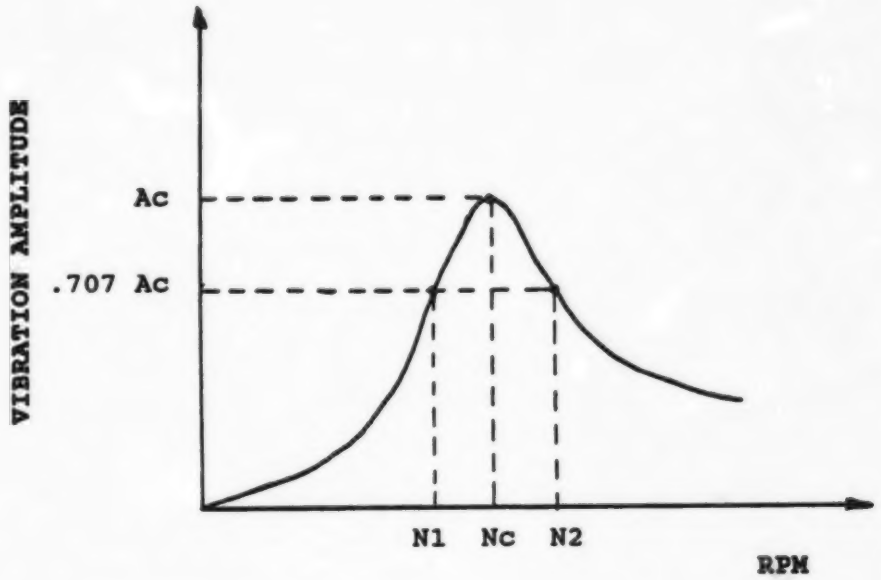
APPENDIX A

COMPENSATION

A Bode plot will be distorted if the signal from the displacement transducer includes any appreciable amount of shaft bow or runout (any deviation in the observed shaft surface which produces a transducer output which is not related to shaft motion). Both shaft bow and runout will create an initial vector or offset in the phase and amplitude portions of the Bode plot. As the shaft speed changes, the bow or runout value (presumably a constant) vectorially combines with true shaft motion to produce the total signal sensed by the transducer. If the bow or runout is a significant portion of the total signal, the appearance of the Bode plot can be greatly altered. These alterations or distortions may include an amplitude peak and phase shift well removed from the actual critical speed, dips in amplitude rather than peaks, or no response in extreme cases.

To circumvent this problem, the displacement transducer signal at a slow shaft speed is obtained and stored. As the shaft speed changes, the slowroll displacement signal can be subtracted from the total displacement signal to yield a signal compensated for shaft bow and runout.

APPENDIX B
DETERMINING AMPLIFICATION FACTORS



Nc = Rotor critical centre frequency (cycles/minute)
N1 = Initial (lesser) speed at 0.707 x peak amplitude (critical)
N2 = Final (greater) speed at 0.707 x peak amplitude (critical)
Ac = Amplitude at Nc

AF = Amplification Factor = $\frac{Nc}{N2 - N1}$